AUGUST 1961
OLUME 4 • NUMBER 8

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- Mayo, Howells & Adams — Generalized Linear Radar Analysis
- Cuccia & Wolkstein — Recent Advances In Low-Noise Traveling-Wave Tubes — Part I

# the microwave journal

ROBT H MAIER-AD MGR
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CHICAGO- ILLINOIS

In This Issue . . . **The Tensor Permittivity Of A Weakly-Ionized Plasma**

# noise figure and automatically radars!

### Separate Modulator, Noise Source

Versatile hp 344AR Noise Figure Meter operates on either a 25 or 30 MC IF frequency. It is designed for pulse radars with repetition rates of 90 to 500 pps; also, its high sensitivity and compact design make it very valuable in all radars, including high PRF and CW Types. In its free-run mode it measures receiver noise figure without turning on the transmitter or radar timing circuitry. Thus periodic measurement and maintenance procedures are simplified.

The 344AR's noise source and modulator are separate units which may be mounted on the antenna mast or in an aircraft. In the first case, high voltage connections are short and beyond slip rings. In the second case, you save weight and space and measure noise figure on the ground through low voltage connections.

### Operation

The hp 344AR measures noise figure by operating a standard noise source and comparing the noise output of equipment under test when the noise source is off to the noise output when the noise source is on. Since the hp 344AR measures in synchronism with the radar, the noise source and measuring circuitry are triggered by a pulse from the radar's timing circuit, occurring at the end of the radar scan.

## SPECIFICATIONS

### hp 344AR Noise Figure Meter

| | |
|---|---|
| Input Frequency: | 25 or 30 MC, as specified |
| Bandwidth: | 1 MC |
| Input Sensitivity: | Requires 35 db ± 5 db gain between noise source and 344AR input |
| Input Impedance: | 75 ohms nominal. Passive termination during radar scan |
| Return Loss: | 20 db from 20 to 40 MC |
| Accuracy: | ± 0.5 db, 0 to 12 db; ± 1 db, 12 to 20 db |
| Repetition Rate: | 90 to 500 pps, as specified |
| Total Duty Factor: | 0.075 + (100 μsec) × (PRF) |
| Input Trigger: | 3 v pos. peak, 3 μsec duration |
| Output: | 100 μamp into 2,000 or 3,000 ohms |
| Temperature Range: | 0 to 52° C |
| Humidity: | 95% |
| Power: | 115 v ± 10%, 50/1,000 cps, 20 to 40 watts (depending on noise source and duty cycle) |
| Dimensions: | 5¼″ high, 19″ wide, 8″ deep. |
| Price: | $1,600.00 approximate. Depends on options and modifications. |

## hp 340B/342A Noise Figure Meters

**General-purpose** instruments making possible, in minutes, receiver and component alignment jobs that once took hours. Simplify accurate alignment; encourage better maintenance; better performance.

**hp 340B** automatically measures, continuously displays noise figure of IF amplifiers or microwave devices with output at 30 or 60 MC. Other frequencies on special order. Operates both temperature limited diodes or hp 347 Waveguide Noise Sources. $715.00 (cabinet) $700.00 (rack).

**hp 342A**, similar, operates on 30, 60, 70, 105, 200 MC. 30 MC and 4 other frequencies between 38 and 200 MC on special order. $815.00 (cabinet) $800.00 (rack).

(Note: Models 340B and 342A available only in the U.S.A. and Canada.)

**hp 343A VHF Noise Source,** temperature limited diode broadband source, 10 to 600 MC, 5.2 db excess noise, $100.00.

**hp 345B IF Noise Source,** 30 or 60 MC (others to order); 4 impedances, 5.2 db excess noise. $100.00.

**hp 347A Waveguide Noise Source.** Argon gas discharge tubes in waveguide sections; for bands S, G, J, H, X, P, 2.6 to 18.0 KMC, 15.2 db excess noise. $200.00 to $300.00.

**hp 349A UHF Noise Source,** 400 to 4,000 MC (wider range with correction), 15.2 db excess noise, $325.00.

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# AT NEW FRONTIERS...

## in . . . Space Research
## and . . . The Application of Recently Obtained Scientific Data

### RESEARCH AND DEVELOPMENT

### DESIGN ENGINEERS

TO PROVIDE TECHNICAL SUPPORT ON SPACE VEHICLE PROJECTS INVOLVING design integration of sub-systems, such as, programming units, receiving systems, reference generators, modulators, antennas, and telemetering equipment.

EXPERIENCED IN THE DESIGN OF

- Transistor amplifiers and video circuits for space probe applications.
- Data processing and display circuits for advanced concepts in ground based communication and radar systems.

### ADVANCED TECHNIQUE DEVELOPMENT ENGINEERS

TO DEVELOP ferrite devices, parametric amplifiers, masers and other microwave solid state devices.

### PROJECT ENGINEERS

BSEE REQUIRED. MSEE DESIRED. MINIMUM OF FIVE YEARS' EXPERIENCE. Needed immediately are men with experience in Radar, Data Processing, and Data Display systems. Must be able to integrate and optimize complex systems. Must be capable of providing engineering direction on microwave systems for Navigation and Tracking. Experience in the design of low noise receiving systems is highly desirable. Efforts are related to Polaris and Deep Space Probe Programs.

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For personal interview send resume, or call Mr. James J. Wright, OLympic 3-3300

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# the microwave journal

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Microwave Two-Phase Converters For Imageless Receivers

The "Cross-Over" Directional Coupler

Recent Advances In Low-Noise Traveling-Wave Tubes — Part II

Long Line Effect In Pulse Compression Radar

"the microwave journal" is published monthly by Horizon House Inc., William Bazzy, President, Executive Editorial offices at 1330 Beacon Street, Brookline 46, Massachusetts, telephone REgent 4-3220.

"the microwave journal" is issued without charge upon written request to qualified persons working at microwave frequencies in the fields of antennas and propagation, electrons and solid state devices, systems, and components manufacturers in the continental United States and Canada, including governmental and university installations. Other subscriptions — continental United States, $10 per year, single copy, $1 when available. In Canada, $15 per year, single copy, $1.50 when available. Other foreign countries, $20 per year, single copy, $2 when available. Copyright© August, 1961 by Horizon House — Microwave, Inc. Accepted as controlled circulation publication at Boston, Massachusetts.

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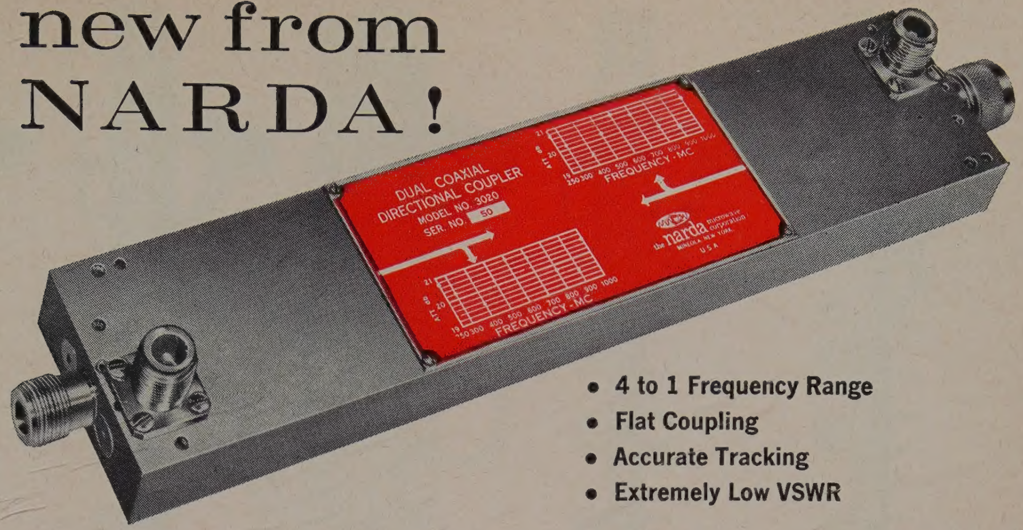
# new from NARDA!



- 4 to 1 Frequency Range
- Flat Coupling
- Accurate Tracking
- Extremely Low VSWR

# high-directivity coax couplers

## Specifically designed for REFLECTOMETER applications!

- Here are two brand new coax couplers, specifically designed by Narda to provide the extremely high directivity needed in Reflectometer setups. And when we say "extremely high directivity", we mean it! For example: Model 3020 (250 to 1000 mc) has a directivity of 35 db minimum, which means a maximum error in VSWR of only 1.035 can occur as a result of the finite directivity. Main line VSWR is held to 1.05 maximum; secondary line VSWR is 1.10 maximum!

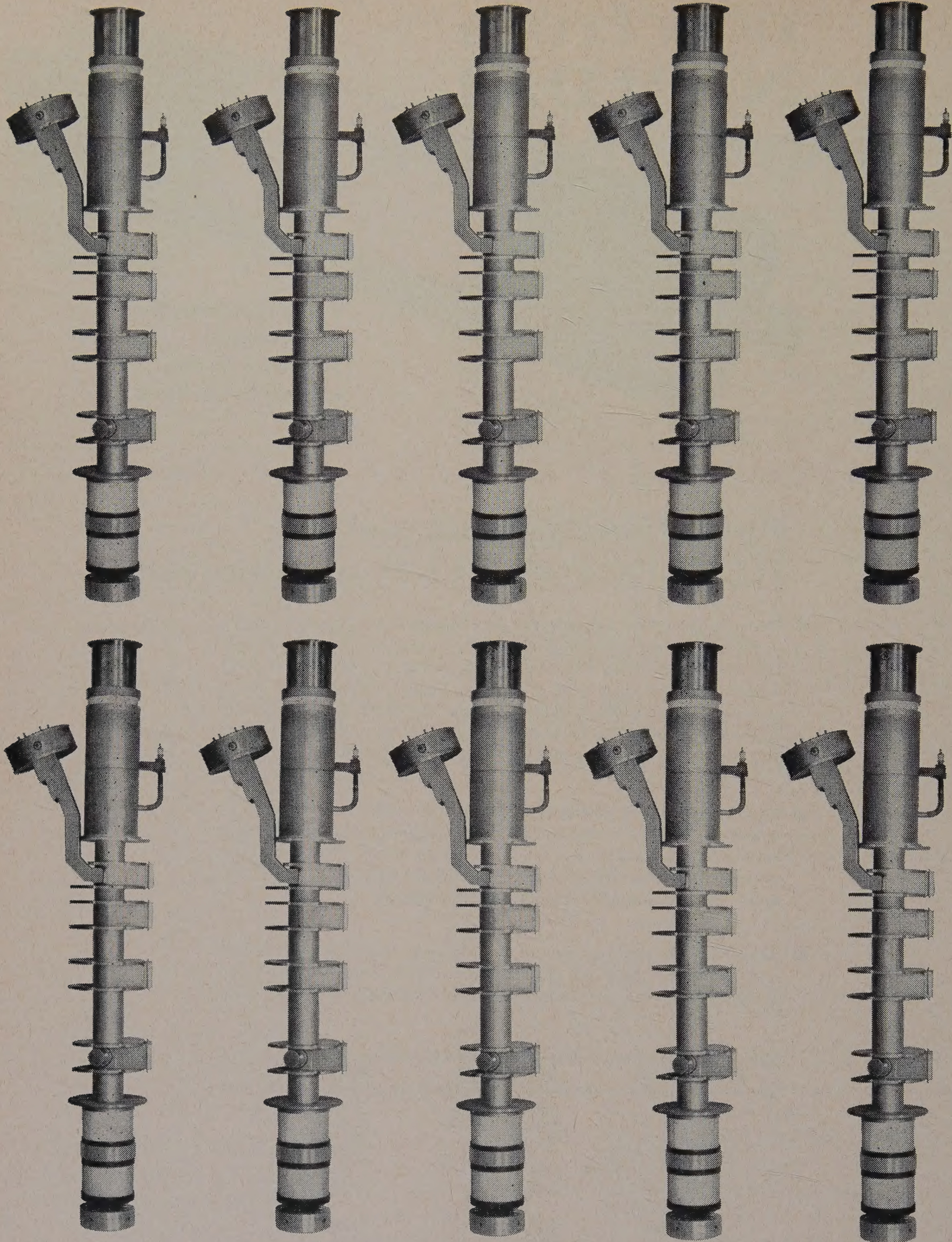
- What's more, each model covers two full octaves; each features extremely accurate tracking (0.3 db maximum change in difference between forward and reverse coupling over the band); each has a power rating of 100 watts CW, 10 kw peak. Check the table for full specifications—and compare with any other units available.

- These are just two examples of the complete line of unusually fine microwave and UHF instrumentation available from Narda. Write today for your free copy of our newest catalog. Address: Dept. MJ-61-4.

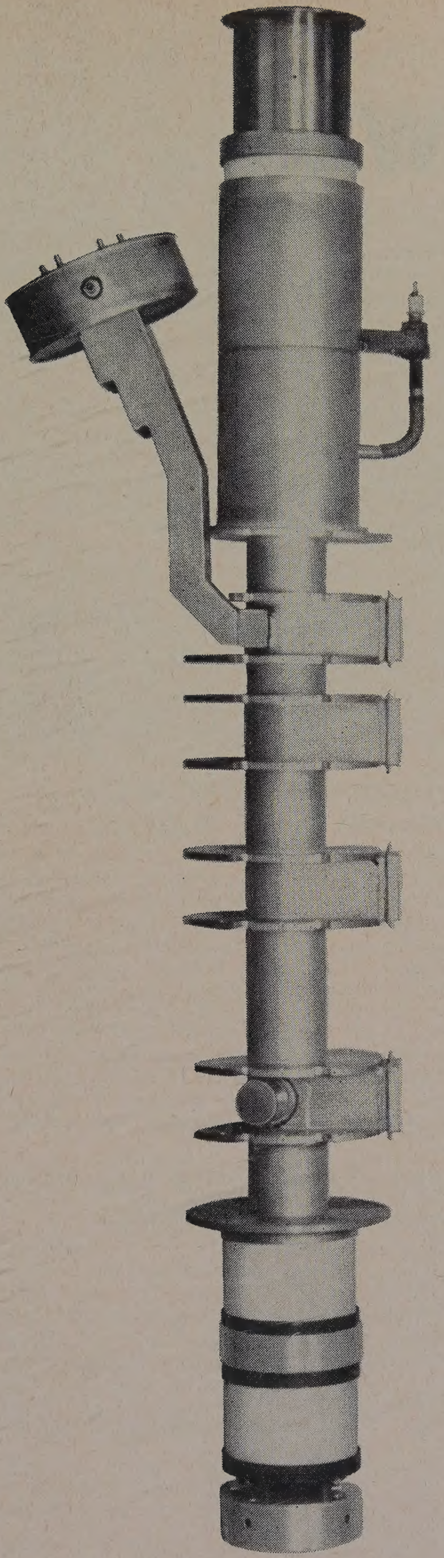
| SPECIFICATIONS | MODEL 3020 | MODEL 3022 |
|---|---|---|
| Frequency | 250 to 1000 mc | 1000 to 4000 mc |
| Directivity | 35db min | 30db min |
| Coupling—both arms | 20db nominal | 20db nominal |
| —Frequency sensitivity | ±0.6db approx. | ±0.6db approx. |
| Max VSWR—main line | 1.05 | 1.10 |
| Max VSWR—secondary lines | 1.10 | 1.15 |
| Power Rating | 100W cw<br>10kw peak | 100W cw<br>10kw peak |
| Tracking | 0.3db total | 0.3db total |
| Price | $200. | $185. |

the narda microwave corporation

118-160 HERRICKS ROAD, MINEOLA, L. I., N. Y. • PIONEER 6-4650



**Today it would take ten super-klystrons to generate more than a megawatt of average power. But now Eimac is ready to do it**



## with one.

Today, the most powerful klystron available can roduce 100KW of average power. But now Eimac s ready to develop a klystron with *ten times* this apability... a klystron that can generate more than ne megawatt of average power!

Impossible? Not for the company that's designed, inanced and built the world's largest high voltage DC power supply (325,000 volts at 10 amps steady current). Not for the company that's made more high power klystrons than any other manufacturer. Not, in short, for *Eimac*. Write for information about this super-klystron capability to: Power Klystron Marketing, Eitel-McCullough, Inc., San Carlos, California.

Eimac

Circle Reader Service Card 2

# MICROVIEWS

## OF THE MONTH

67 ▶ **THE TENSOR PERMITTIVITY OF A WEAKLY-IONIZED PLASMA**

**R. S. Elliott**

*This review paper begins with a description of the atmosphere and conditions under which it can become a weakly ionized plasma. Interactions between the plasma and electromagnetic waves give rise to important engineering problems. Laboratory simulation of these problems requires an understanding of the interaction in the presence of dc electric and magnetic fields. Central to an understanding of the interaction is the concept of the complex tensor permittivity of the plasma. A derivation of this permittivity relation is presented which proceeds from Newton's force law and uses statistical methods to account for collisions. The major solutions of the tensor wave equation are briefly discussed.*

74 ▶ **A 20 KW CW X-BAND KLYSTRON AMPLIFIER**

**E. McCune, I. Maltzer, and L. T. Zitelli**

*This paper describes general design considerations and performance characteristics for a 20-kw, cw, four-cavity klystron amplifier operating at 8.35 kMc. Some of the problems involved with transmitting 20-kw, cw power at X-Band are also discussed, and solutions which produced satisfactory performance in the laboratory are given.*

79 ▶ **GENERALIZED LINEAR RADAR ANALYSIS**

**B. R. Mayo, P. W. Howells and W. B. Adams**

*For analysis many radar systems can be considered to be a cascaded system of linear networks. The transmitter is an impulse generator followed by a network whose transfer function is equal to the frequency spectrum of the transmitter it represents. The transmit antenna is a network whose transfer function is the steady-state single-frequency radiation field of the antenna. The target is assumed to be a point target producing only doppler effects. The receive antenna transfer function is similar to that of the transmit antenna, differing primarily in the absence of a differentiation of the time waveform which the transmit antenna performs. The receiver is represented by a filter matched to the return echo for zero doppler and boresight antenna conditions. For an isotropic transmit antenna, with certain restrictions, the ratio of the square of the peak magnitude of the four dimensional ambiguity function in range, doppler, and the two spatial angles to the volume under the magnitude-squared of this function is the reciprocal of the receive antenna beam area and is independent of the signal waveform used.*

85 ▶ **RECENT ADVANCES IN LOW-NOISE TRAVELING-WAVE TUBES — Part I**

**C. L. Cuccia and H. J. Wolkstein**

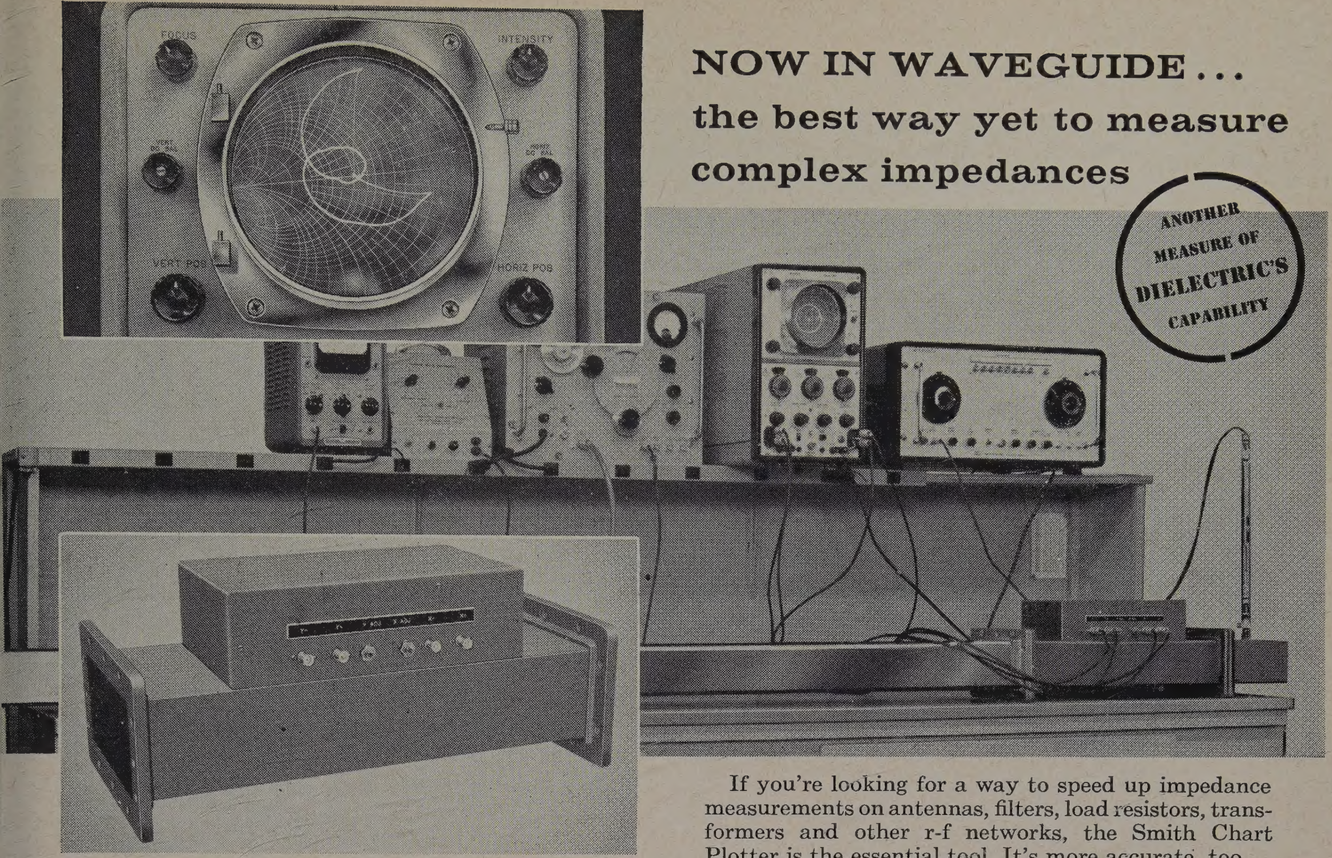
*By 1956, noise figures of 6.5 db were obtainable for solenoid-focused mid-S-band forward-wave traveling-wave tubes using low-noise medium-bandwidth couplers and large solenoids. Since that time, continued development of the couplers and electron guns of such low-noise tubes has yielded reproducible noise figures below 4 db in S-band and L-band. There have also been concurrent developments in focus structures for wide-band low-noise traveling-wave tubes focused by aluminum-foil solenoids and by periodic-permanent-magnet structures. Noise figures as low as 6 db have been achieved for very-wide-band solenoid-focused tubes, and noise figures from 10 to 15 db have been achieved for periodically focused tubes. The features which have made these advances possible are described in this paper.*

### OUR COVER

The cover photograph shows the VA-849, a new amplifier klystron which delivers output power in excess of 20 kilowatts CW at X-band. Modifications of this tube have delivered over 50 kilowatts under laboratory conditions. The VA-849 is expected to have application in earth-to-satellite communications, radar astronomy, missile illumination, and orbital scatter communication. See page 74.

*Photograph courtesy of Varian Associates*

# NOW IN WAVEGUIDE . . .
## the best way yet to measure complex impedances



Here is the first major breakthrough in the measurement of complex impedance over a band of frequencies. For speed, simplicity, and reliability, it surpasses anything yet used. It's the Smith Chart Plotter, developed by Dielectric Products Engineering Company to obtain instantaneous Smith-Chart display of reflection coefficient as a function of frequency.

Recently 50-ohm coaxial models were announced. *Now these instruments are available in waveguide as well.* Five resolver models span the range 350 to 12000 mc/s. Calibrated mismatch loads are also available.

This unique instrument — along with appropriate auxiliary equipment to form the complete plotter — eliminates the need to tie up highly skilled technical personnel during prolonged test routines that characterize slotted line measurements.

### HOW IT WORKS

With Dielectric's Smith Chart Resolver, a swept-signal generator sweeps repetitively over the frequency band desired. The reflection coefficient of the unknown load is resolved into its X and Y components, which are then applied to the X and Y amplifiers of an oscilloscope equipped with a Smith Chart faceplate. A continuous trace of reflection coefficient versus frequency is thus displayed directly. The faceplate can be either a full-scale chart, or one expanded to 1.5:1 VSWR.

As load changes or adjustments are made, impedances change. Simultaneously so does the trace . . . load changes are observed immediately. When a permanent record is required, the oscilloscope trace may be directly photographed. Or, if preferred, an X-Y chart recorder may be used.

If you're looking for a way to speed up impedance measurements on antennas, filters, load resistors, transformers and other r-f networks, the Smith Chart Plotter is the essential tool. It's more accurate, too.

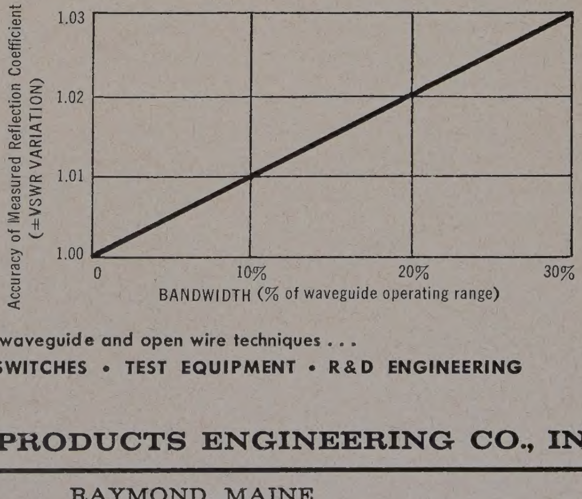
And there is more to come. For the measurement of r-f impedance in systems at any power level to the highest that can be generated, in either waveguide or coaxial line, other forms of the plotter will soon be available to supply a Smith Chart display. These will be particularly useful as system monitors.

### SPECIFICATIONS

| | |
|---|---|
| Nominal impedance | $Z_0$ (Waveguide) |
| RF input voltage | 0.35 volts, rms |
| Oscilloscope signal voltage | 0.2 volts input required for full scale deflection on expanded Smith Chart (1.5 VSWR max) for DC oscilloscope having 1 centimeter/millivolt sensitivity |
| Accuracy of reflection coefficient measurement | see graph below |
| Sweep rate (maximum) | 60 sps |
| Spot rotation rate (maximum for full accuracy) | 1000 rev/sec |
| RF input-output terminals | Optional |
| Automatic level control terminals | BNC (where required*) |

*ALC information supplied with unit.

For complete description, ask for Bulletin 60-3. You'll get the latest revision and supplement which include both waveguide and coaxial units.



Other areas of **DIELECTRIC** capability in coaxial, waveguide and open wire techniques . . .

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# ONCE UPON A TIME

Once upon a time three microwave engineers who worked for a large electronics company decided they wanted to go into business for themselves.

They felt that with their own company they could do the types of things they preferred and make money doing it.

After careful study, they arranged to get financial backing from a group of venture capital people. They set up their first office and laboratory in a loft.

Because of their special talents, they decided to concentrate on making ferrite devices. In addition to working as microwave engineers, they became business men and salesmen and janitors and purchasing agents and shippers and many other things. And every day they waited for the mail. The first day an order came they were on top of the world. The first large check sent them into orbit. And because they were talented and had nothing more important to do, they were able to set a spectacular pace for price, delivery, and performance.

By the end of the second year they were financially in the black. They had 25 employees, larger quarters, and a line of catalogue items. They were also devoting a large fraction of their effort to government sponsored sub-contract work.

They were still setting a spectacular pace for performance; prices were beginning to rise slightly; and delivery was slipping on a few items. The total picture was one of strength with the promise of growth.

More time passed. They added more people of all types, sales, financial, as well as technical. Overhead began to grow. But volume was increasing to keep pace. Profits were good, and the company was no longer a small operation. The catalogue was expanded to include all the new items that had been added. They now became businessmen — administrators. But now they didn't have to wait for the mail or the orders or the checks.

The company kept growing and finally went public. Each of the original three became wealthy men — but they were no longer doing the engineering work they had preferred.

And as the company grew, the original enthusiasm and drive began to fade. For the most part, prices were competitive, delivery was normal, and performance was good. The new people that came had no feel or understanding for what the company had originally been.

To them it was a large electronics company.

And one day three of the senior microwave engineers decided they wanted to go into business for themselves.

Ted Saad

# *New multi-purpose*
# BROADBAND FERRITE AM MODULATOR

**DELIVERY FROM STOCK**

**MODEL X158A**
**Price: $250.00**

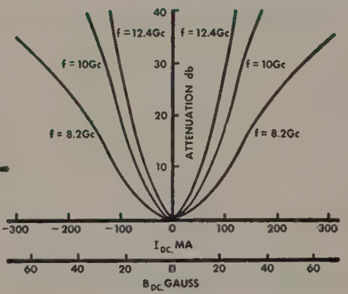
## First to cover the entire X-band, 8.2 to 12.4 Gc

FXR's new X158A broadband ferrite modulator is the first absorption amplitude modulator to provide full coverage of X-band, 8.2 to 12.4 Gc. A primary use of this unit is to provide a clean AM microwave signal for high accuracy measurements. Previously any attempt to modulate a microwave oscillator left much to be desired because of error-producing FM, jitter and double moding.

The modulator coil of the X158A has been designed so that any standard, 1 watt, commercial audio oscillator will provide substantially 100% modulation at 1,000 cps.

- Covers entire X-band, 8.2 to 12.4 Gc
- Metallized plastic construction for high frequency audio response
- Low driving power required
- 30 db minimum dynamic attenuation
- Low insertion loss—with no coil current

**ATTENUATION-SOLENOID CURRENT**



## APPLICATIONS

### Microwave Measurements

As an amplitude modulator for high accuracy microwave measurements

### Microwave Transmitter Modulation

With proper biasing of the control solenoid low distortion modulation is obtained over the audio range

### Fast Microwave Switching

For front panel or remote switching of signal generators and other low power units

### Electrically Controlled Microwave Attenuation

For electrically controlled microwave attenuation of system energy from either remote or local positions

## SPECIFICATIONS FOR MODEL X158A FERRITE MODULATOR

**Freq. range:** 8.2 to 12.4 Gc
**Max. insert loss:** 1.0 db
**Min. dynamic attenuation:** 30 db
**Max. input and output VSWR:** 1.20
**Max. average RF input power:** 2 watts
**Coil characteristics:** 35 millihenries 55 ohms @ 1 kc
**Max. solenoid current:** 300 ma DC
**Insertion length:** 5″
**Cover flanges to mate with:** UG-39/U
**Waveguide type:** WR90

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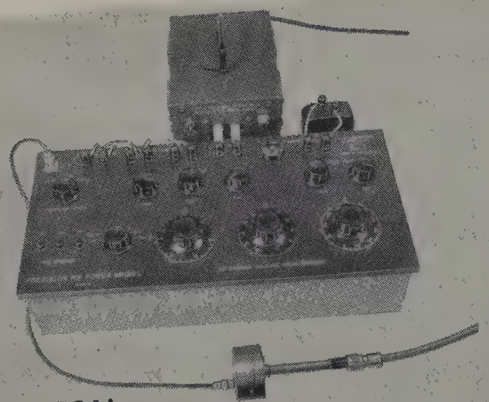
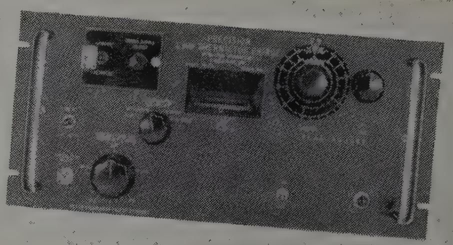
# THE MOST ACCURATE R. F. POWER MEASURING SYSTEMS



## UNIVERSAL PRECISION DC BRIDGE

**Model PB-1**

The Model PB-1 is a DC substitution bolometer bridge capable of accuracies to 0.1% in the measurement of substituted DC power. It is used in standards laboratories which require the highest attainable accuracy in high frequency power measurements. It is also used in the transfer of calibration factors from one bolometer mount to another. When used for very precise measurement of insertion loss up to about 10 db, this measurement becomes directly traceable to DC resistance and voltage standards.



## SELF-CONTAINED DC THERMISTOR BRIDGES
### For 1.0 and 10.0 Milliwatts
### Models TB-2A and TB-3

**Uses:**

- Calibration of output level of standard signal generators
- Calibration of bolometer mounts
- Power monitor in precision measurements requiring constant power level
- Establishing known R. F. power levels for calibration of power meters and other power sensitive devices

**Specifications:**

R. F. Power Level: TB-2A—1.00 mW/TB-3—10.0 mW
Accuracy of Substituted DC Power: ±0.15%
Calibration Factor Range: 0.85 to 1.05, adjustable in steps of 0.01.

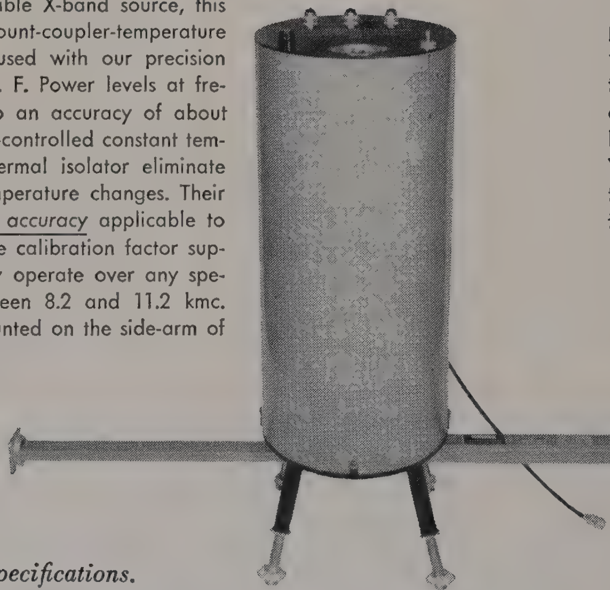
## CALIBRATED BOLOMETER MOUNTS

### Models 811, 813 and 815 X-Band Power Standard

In combination with a stable X-band source, this 200 ohm thermistor mount-coupler-temperature chamber combination is used with our precision DC bridges to establish R. F. Power levels at frequencies in the X-band to an accuracy of about 1.1%. The thermostatically-controlled constant temperature chamber and thermal isolator eliminate the effects of ambient temperature changes. Their stability preserves the 1% accuracy applicable to the NBS test report for the calibration factor supplied with each unit. They operate over any specified 200 mc band between 8.2 and 11.2 kmc. They are permanently mounted on the side-arm of a 3 db directional coupler.

### Model 675-A Coaxial Thermistor Mount

This 200 ohm thermistor mount is used with our precision DC bridges to measure R. F. power, in the 100 to 4000 mc range. The very long thermal time constant of the bolometer mount virtually eliminates ambient temperature changes. This stability preserves the calibration factor supplied by Weinschel Engineering at 400, 1000 and 1500 mc to an accuracy of 2%. Calibration factors at other frequencies are supplied on special order.



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# to buy the JVM Triode Cavity you need

Why? Because much of the engineering and fabrication is already completed.

JVM has engineered and constructed over 350 *different types* of triode cavities — by far the most complete selection available. Usually, one of these types, standard or slightly modified, will exactly meet your prototype requirements. Often, several standard interchangeable parts can be used in fabrication and assembly, permitting the unusually short 30 day delivery schedule and pleasantly low cost. Totally new designs take a little longer and cost a little more.

Plan now to discuss your triode cavity needs with JVM. Write for the new technical brochure, complete with performance data, on JVM TRIODE CAVITIES.

JVM DIVISION OF — **Fidelitone Microwave Inc.**
Chicago 26, Illinois

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# Industry News

### BACKUS ASSUMES POST OF CORPORATE COORDINATOR AT SANDERS

Paul Hunter Backus, Commander, U.S.N., Ret., has joined Sanders Associates, Inc., Nashua, N. H., as Corporate Coordinator, a newly created post, Royden C. Sanders, Jr., president, has announced. Mr. Backus will report directly to the president and will initially work on special assignments.

Before joining Sanders Associates, Mr. Backus was head of the Ballistic Missile Group on Admiral Arleigh Burke's staff in the Office of Chief of Naval Operations. Since 1956 he was a member of top level Navy groups in the Pentagon that originated and carried out the Polaris missile program.

During this time he was executive secretary and a member of the Navy Ballistic Missile Committee which is headed by the Secretary of the Navy as Chairman. The committee set policy and supervision of the entire Fleet Ballistic Weapon System and carried the Polaris concept from idea to fleet operation. He was twice cited for his service with award of the Secretary of the Navy's Commendation.

*—mwj—*

### PRELIMINARY PROGRAM FOR WESCON MAILED OUT

The preliminary program for the 1961 Western Electronic Show and Convention has been mailed, giving particulars on the technical convention exhibitors, field trips and the many attendant social events available in San Francisco during August 21-25

More than 80,000 copies of the program reached western members of the Institute of Radio Engineers and the Western Electronic Manufacturers Association, co-sponsors of the West's largest technical convention and trade show, and other IRE members, exhibitors and persons who have participated in WESCON in recent years.

The 16-page publication offers a first reading of the technical program, which is expected to attract upwards of 35,000 engineers and various management levels of the electronics industry to the Cow Palace during the four-day period of WESCON.

Satisfaction with the quality and scope of the papers has been expressed by the executive committee of the WESCON board of directors, which has the overall responsibility for this year's activities in San Francisco.

*—mwj—*

### ADVANCED RADAR DESIGN AWARD RECEIVED BY SYLVANIA

Receipt of a multi-million dollar award for the development of an advanced radar design for possible future incorporation into the U. S. Army's Nike-Zeus anti-missile missile system has been announced by General Telephone & Electronics Corp., New York, N. Y.

The award was made to the Waltham Laboratories of Sylvania Electric Products Inc., a subsidiary of GT&E, by the Bell Telephone Laboratories, which is responsible for Nike-Zeus system design and development. Western Electric Company is prime contractor on the Nike-Zeus program through the New York Ordnance District.

The Nike-Zeus system is being developed to provide a defense of the continental United States against the threat of intercontinental ballistic missiles.

Work on the radar will be carried on as part of the basic Nike-Zeus development effort, and as part of the Army's plan to incorporate advances in technology in the Nike-Zeus system on a continuing basis. Recent improvements in radar technology have made such an effort feasible.

*—mwj—*

*(Continued on page 18)*

MEC *Reports*

■ *S, C and X-Band, Metal-Ceramic, PPM Focused, Magnetically Shielded, 10 mw Output and 30 db Gain with Maximum Broadband Noise Figure of 10 db.*

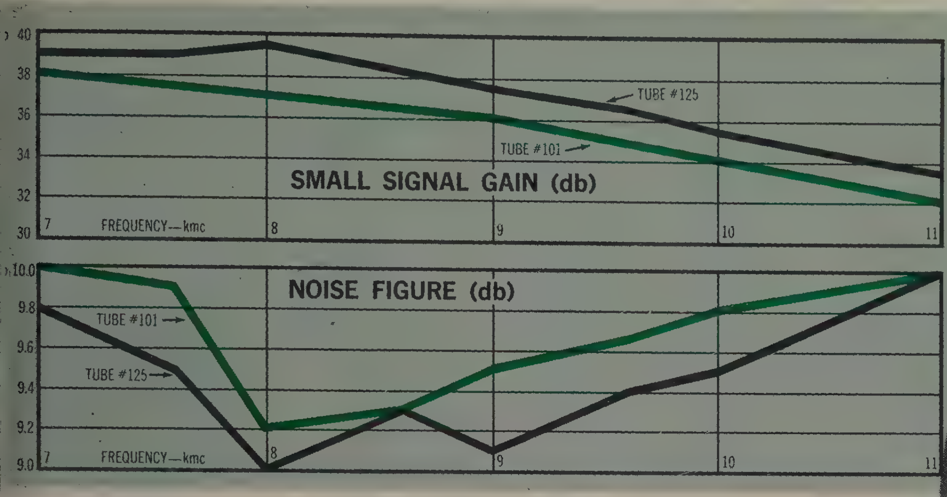
Typical of MEC's advanced family of metal ceramic low noise traveling-wave tubes is the new M2105. Rugged and reliable, this tube is the result of engineering skill and manufacturing care appropriately combined to form a production tube with truly reproducible characteristics.

Shielding of the tube and its focusing structure, an advantage of the PPM format, eliminates the effect of stray magnetic fields and permits use of tubes in close proximity to magnetic materials or to each other. Elimination of the focusing solenoid and power supply reduces power consumption to less than 3 watts, including heaters, and does away with auxiliary cooling.

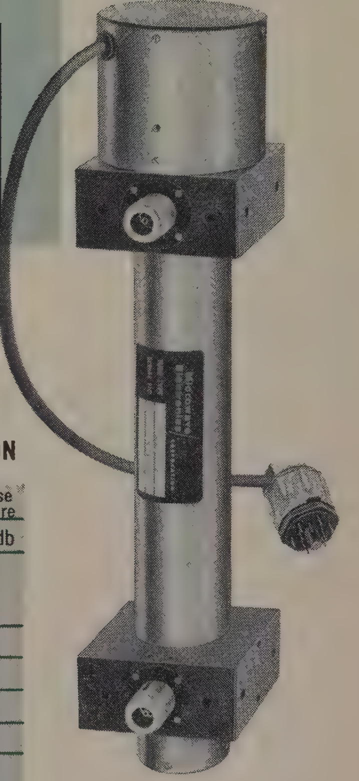
*Ask for your copy of our new*

"SEE US AT WESCON BOOTH 1108"

# ow Noise TWT's with PPM Focusing



REPEATABILITY MEANS RELIABILITY.
Notice how closely the small signal gain and noise figure characteristics for the first M2105 (#101) compare with those of the last member in the first lot (#125).



Model M2105 Low Noise TWT weighs 5 pounds and is 12⅝" long.

### ility—
### lt-in Feature of MEC Tubes

al-ceramic construction gives
C tubes a headstart on reliability.
are evacuated at higher temper-
s (650°C), producing a higher
um and cleaner environment for
cathode life.

ently rugged, they provide supe-
performance over environmental
emes. (The M2105 withstands
shock and 15 g vibration between
l 2000 cycles with no degradation
rformance. Temperature compen-
n work is now being completed.)

C construction features also in-
e a stacked ceramic gun and a
x rigidly supported by three
mic rods. Critical turn spacing is
rately maintained to assure uni-
gain characteristics from tube-
be. The tube can be operated in
position without change in char-
istics.

### TYPICAL LOW NOISE TWT TUBES IN PRODUCTION

| PPM FOCUSED TUBES | Frequency Range | Small Signal Gain | Saturation Power | Noise Figure |
|---|---|---|---|---|
| M2103 Series (Family) | 2 - 4 kmc | 30 db | 10 mw | 10 db |
| | (over 0.5 kmc portion of the band) | 30 | 10 | 8 |
| | 2.3 - 4.4 | 30 | 10 | 10 |
| | 2 - 4 | 30 | 10 | 15 |
| M2112 Series | 4 - 8 | 30 | 10 | 10 |
| | 4.3 - 7.4 | 30 | 10 | 10 |
| | 4 - 8 | 30 | 10 | 15 |
| M2105 Series | 7 - 11 | 30 | 10 | 10 |
| | 7 - 11 | 30 | 10 | 15 |
| | 8 - 12.4 | 30 | 10 | 15 |
| M2114 | 12.4 - 18 | 30 | 5 | 14 |
| SOLENOID FOCUSED TUBES | | | | |
| M2103 Series | 2.0 - 4.0 kmc | 30 db | 5 mw | 8 db |
| | (over 0.5 kmc portion of the band) | 30 | 5 | 6 |
| M2107 | 4.0 - 8.0 | 30 | 5 | 10 |
| M2101 Series | 7.0 - 11.0 | 30 | 10 | 9 |
| M2114 | 12.4 - 18.0 | 30 | 5 | 12 |

MEC's new short form catalog with complete information on our production engineered line of traveling-wave tubes is available now. In addition to low noise types, the catalog covers medium and low power, serrodyne, and special purpose tubes. For your free copy, call your nearest MEC engineering representative or write to us.

MEC

MICROWAVE
ELECTRONICS
CORPORATION
4061 Transport Street
Palo Alto, California
DAvenport 1-1770

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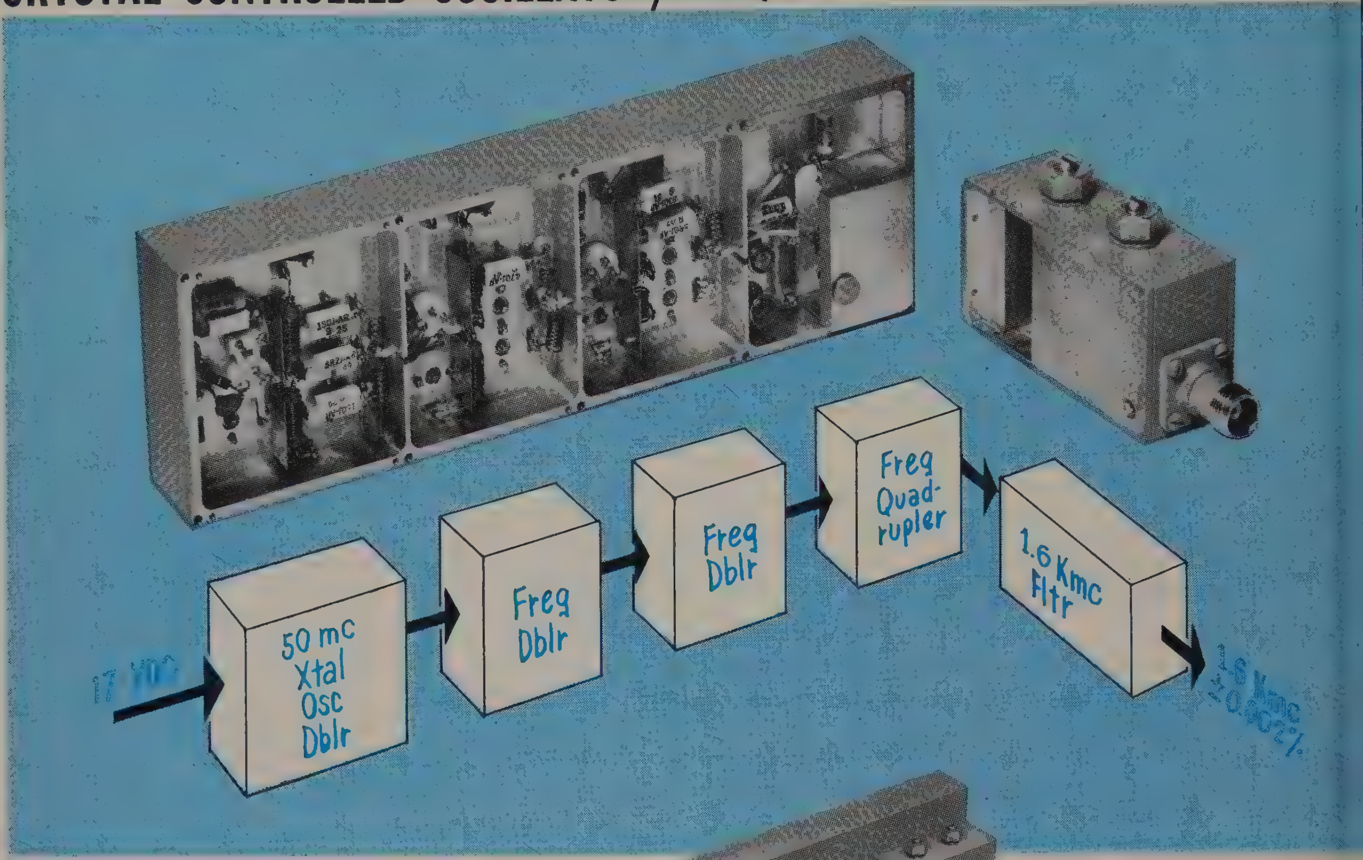
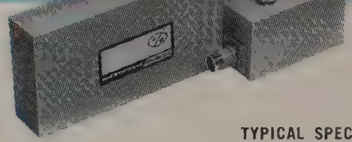
# ALL SOLID STATE
# CRYSTAL CONTROLLED OSCILLATOR/FREQUENCY MULTIPLIER CHAIN





## Series SO (L and LS Bands)

Rugged — all solid state — crystal accurate . . . the Series SO sources offer optimum weight/performance balance.

As local oscillators and parametric pumps in transmitters or receivers, they are ideally suited to missile and space-vehicle instrumentation.

**TYPICAL SPECIFICATIONS**

| | |
|---|---|
| **Frequency Range** | 1.12 — 2.60 kmc |
| **Power Output** | 1.25 mw min |
| **Frequency Stability** | Better than ±0.002% |
| **Output Impedance** | 50 Ohms, or as req'd |
| **DC Power Input** | 17v @ 35 (max) ma |
| **Size** | 22 cu in (7½″ long) |
| **Weight** | 18 ounces |
| **Output Connector** | Any Standard RF Fitting |

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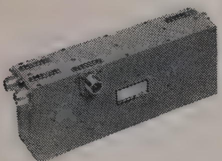
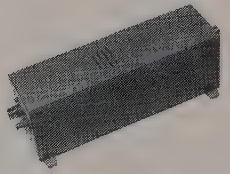


**HIGH POWER TRIPLEXER** — for simultaneous operation at HF, Communications and TACAN bands — provides 40 db channel isolation.

| Channel | Freq Range, mc | Passband IL | CW Power |
|---|---|---|---|
| 1 | 3– 30 | 0.1 db max | 500 W |
| 2 | 200– 400 | 0.5 db max | 150 W |
| 3 | 950–1215 | 0.1 db max | 250 W |



**BANDPASS FILTER** (104-122 mc) — featuring a low insertion loss and a maximum VSWR of 1.15:1 in its passband, this unit can carry 150 Watts of continuous power. A high degree of attenuation is provided for signals below 90 mc and in the range from 130 to 1000 mc. Has calibrated power-sampling terminal at the output port.

**MICROPHASE CORPORATION**

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R & D Facilities in Cos Cob, Connecticut

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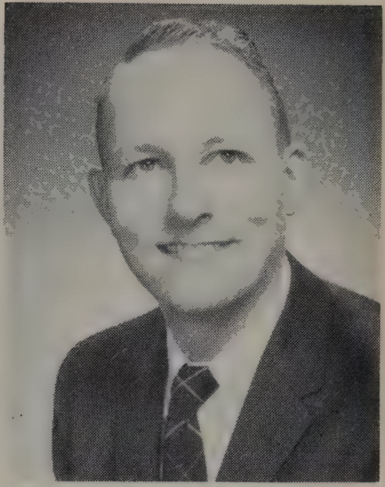
*. . . MANY . . . PAPERS . . . ARE JUST REHASHES."*

# TWO FAMOUS INVENTIONS



**ROBERT C. HANSEN,** ASSOCIATE EDITOR, *the microwave journal*

In a humorous guest editorial in the September, 1958 GIT Transactions, Peter Elias wrote about "Two Famus Papers." These were two papers which, according to im, had been written over and over again. The first aper of which a typical title was "Information Theory, hotosynthesis and Religion", discussed the interesting act that concepts of structure, pattern, entropy, noise, nd code are common to information theory and a number of other fields including psychology, genetics, nguistics, psychiatry, etc.

To quote from Elias, "Having placed the discipline of sychology for the first time on a sound scientific base, ne author modestly leaves the filling in of the outline o the psychologists. He has, of course, read up on the eld in preparation for writing the paper, and has a firm rasp of the essentials, but he has been anxious not to lutter his mind with such details as the state of knowedge in the field, what the central problems are, how ney are being attacked, etc."

The second paper covers a physical problem involving ltering, noise, and a certain shape or type of signal. gain from Elias, "An effective discussion of this nonnear problem would require some really new thinking f a difficult sort, so the author quickly substitutes an nrelated linear problem which is more amenable to nalysis. He treats this irrelevant linear problem in a very eneral way, and by a triumph of analytical technique is ble to present its solution . . . in a form in which standrd numerical techniques can provide answers to specific uestions." He goes on to state that the author usually ucceeds in showing that the only cases which can be andled reduce to those already analyzed by Wiener-Leeadeh-Raggazzini years before.

This subject, which is not without parallel in the microvave business, prompted me to write about two famous evices which over the years have been invented over nd over again by different people in different places. nfortunately, these two devices, which have the generic escription of miniaturized quarterwave monopole antenas, are based on fallacious reasoning.

In the first invention, someone faced with the problem f erecting a quarterwave monopole above ground (or n a vehicle, etc.) at frequencies low enough for the eight to be difficult, gets the clever idea that by simply oiling up the long wire into a tight spring the reactance an be made the same, even though the physical height is now much shorter. The next step is for the inventor to proclaim that he has found a monopole radiator which is every bit as good as the quarterwave monopole and so very much shorter and more compact. Further claims usually include that the impedance can be made exactly the same as the long-wire monopole.

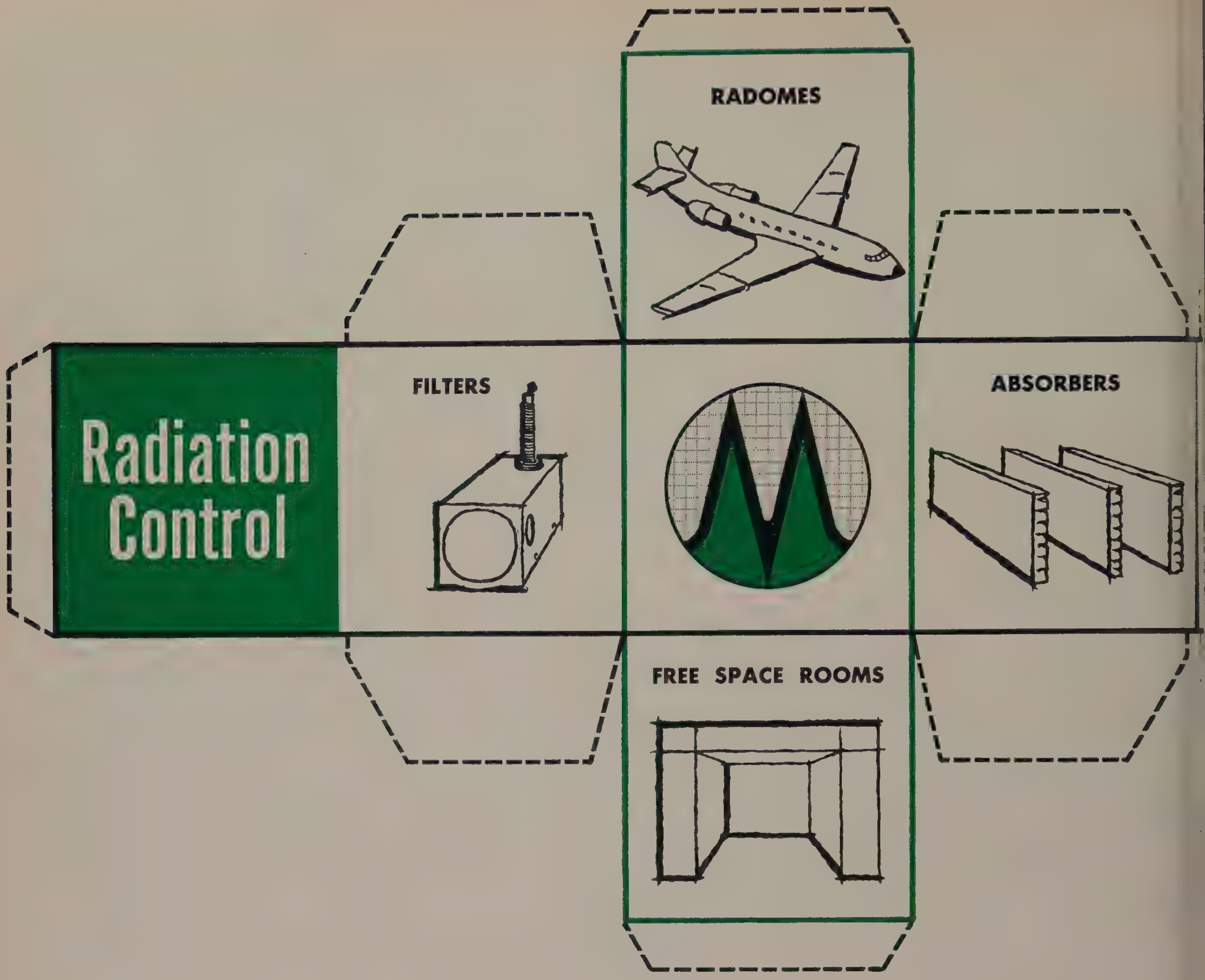
There is an element of truth in this proposition, in that a *short* straight wire has essentially a triangular current distribution, and by inductively loading this wire along its length, a distribution of current can be produced whose effective value is higher than one-half. However, the effective length of this antenna is always bounded by the physical length and is often closer to half that value. Thus the input resistance of the miniaturized monopole may be equal to that of the longer straight monopole, but the radiation resistance (which is the important parameter for transmitting) is essentially that of a short wire. Of course, by making the turns of the spring large in wavelength, a helix mode can be produced, but this is a separate situation.

Despite the fact that the above represents elementary antenna theory which can be found in many excellent textbooks including those by Krausz, Jordan, and Schelkunoff, it was as recent as last year that an article was published citing the replacement of a tall transmitting tower by a low coiled spring monopole. I am under no illusions that this editorial will prevent this fallacious device from being reinvented in the future, but perhaps it will encourage a few inventors to try some other field, perhaps impulsing vehicles without a friction contact!

The second famous invention is also a miniaturized quarterwave monopole. This time the trick is so simple that one wonders why it was not invented long before. Everyone knows that in order to radiate a wave into space one should match the wave impedance on the wire antenna to free space wave impedance, and this it seems can be done by a matching section made of appropriate dielectric material. Thus the short monopole is potted in a large mound of dielectric chosen with the right dielectric constant and, of course, low loss. This device, it is often claimed, is equivalent to the full-size monopole.

The reason that this wasn't invented long ago is simply that it doesn't work. This is one of those cases where

*(Continued on page 17)*



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Complete Package for Radiation Control!!

. . . . . Whatever your application — for ground support systems, for airborne radar, or for combinations of both — the keynote in radiation control is *compatibility*. Radomes, absorbers, "free space" rooms, R. F. filtering devices — all are instrumental in the control of radiation. The compatibility of these items is vital to proper functioning of the antenna system.

Only McMillan offers you a truly extensive background of engineering in the design, development and manufacture of *all four* of these products. McMillan innovations in radomes, absorbers and special filtering devices remain firsts in their fields. Pre-design consultation is another feature of McMillan engineering service. That's why users of McMillan products form a veritable "Who's Who" in the field of electronics.

Isn't it logical that you, too, can best obtain complete compatibility of the radiation control elements you require by specifying the manufacturer who offers the complete package.

**THE McMILLAN COMPANIES**
BROWNVILLE AVENUE · IPSWICH, MASSACHUSETTS
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(Continued from page 15)

pplication of naive concepts gives the wrong answer. In act, Schelkunoff some years ago in one of his books rgued, basing his argument on the quasi-static analysis f a short monopole, that enclosing the monopole in ielectric material would, in fact, degrade the radiation esistance or effective length. You might expect that ords from so well respected an authority as Schelkunoff ould quell this nonsense permanently. However, with he advent of ferrite materials, there are those who have een casting about for all sorts of schemes in which to mploy ferrites, and this one seemed ripe for the plucking.

Two years ago at the Toronto URSI Electromagnetic heory Symposium, Polk presented a paper which analyzed a similar problem. He showed that a dielectric material in proximity to the antenna degraded the performance until the dimensions/constitutive parameters were ufficiently large to produce internal resonance. In this egime the antenna acts as a supergain device with a high ntrinsic Q and consequent rapid oscillation of parameters. It is reassuring that Polk has put the refutation of he dielectric-enclosed monopole on a sound scientific asis. Here again, however, I am sure that the idea will ecur, especially if a new material is devised.

In the introduction I alluded to the possibility that the icrowave field might have its share of famous papers, nd I would like to mention just one. It has become popular in the communications business these days, especially n the glamorous field of space communications, to write paper entitled something like "Optimum Frequencies or Space Communications".

The time budget for writing this paper is as follows: opying the range equation out of some convenient reference—½ hour; making off-the-top-of-the-head guesses n antenna gain restrictions, vehicle weight/power restrictions, capabilities of transmitting tubes and devices, tc.—2 hours; checking the literature to make sure no ne else has used exactly these same boundary conditions —2 hours; calculating range and performance curves sing the assumed boundary conditions and well-known ntenna noise temperature data from *microwave journal*, of ourse—3 hours, and writing all of this up, with results hat the optimum frequency is between 1 and 10 gc with maximum likelihood in the vicinity of 3 gc—4 hours.

All together, this earth-shaking paper has taken a total f 11½ hours! The trouble is analogous to that in Elias' amous papers. Essentially, no contribution is made past he early work of Pierce-Mueller-Raisbeck. In addition to ewriting this paper with different assumptions on antenna gain, etc., the paper is sometimes rewritten to include different type of modulation, and I suspect that whenever a different modulation system is being considered or space application, someone will write about optimum requencies for this kind of system. Some of the extant apers are, of course, valuable, but many more are just ehashes. This is probably true in any exciting new field. would write more on this subject except that time is rowing short and I just barely have enough hours left o finish my paper on "Optimum Frequencies for Space ommunications".

WHEELER
Laboratories, Inc.
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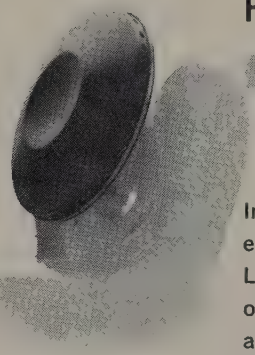

In the field of microwave engineering, Wheeler Laboratories on Long Island occupies a unique position as an industrial laboratory devoted exclusively to consulting and development.

As a service to many prominent laboratories and manufacturers, WL designs radar and communication antennas, waveguide components, and microwave assemblies. Your inquiries are invited.

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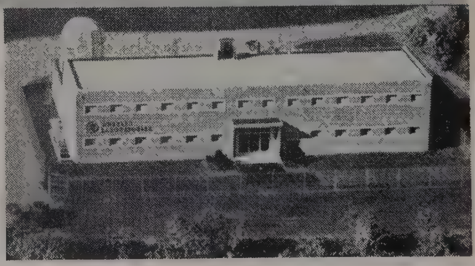

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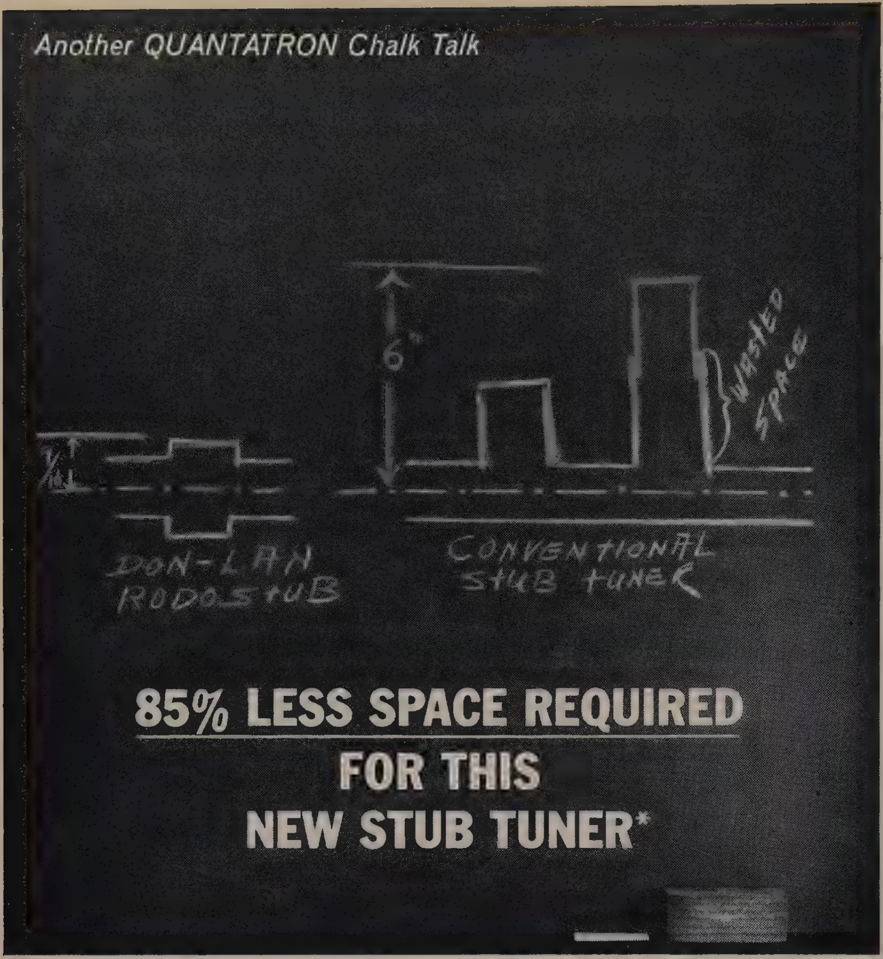
and Engineering Staff


Another QUANTATRON Chalk Talk
1/4"
6"
WASTED SPACE
DON-LAN RODOSTUB
CONVENTIONAL STUB TUNER
85% LESS SPACE REQUIRED FOR THIS NEW STUB TUNER*

RODOSTUB,® the new ROtary DOuble STUB tuner by Don-Lan, makes in-line tunable transmission lines possible. Designed for military environments, the compact RODOSTUB with its firm locking device occupies only 1/6 the space of conventional double stub tuners.

Model S-100 RODOSTUB shown here covers 1.0 to 10.3 Gc. Its bigger brother, MODEL S-200, covers 0.1 to 2.0 gigacycles. Both series feature the unique Don-Lan in-line rugged construction.

ACTUAL SIZE

* Patent No. 2,966,642

RODOSTUB is only one of the unique line of Don-Lan microwave products produced by Quantatron. Write for details. Consult our engineering staff on your microwave requirements.

*Quantatron, Inc.*
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**Quantatron offers its microwave products through its components division...**
**Don-Lan Electronics, Inc., 2520 Colorado Blvd., Santa Monica, California**

## Industry News

*(Continued from page 12)*

### HOLDAM NAMED VICE PRESIDENT AT DRESSER

H. N. Mallon, chairman of the Board of Dresser Industries, Inc., Dallas, Tex., has announced the election of J. V. Holdam as vice president in charge of the firm's electronics activities.

Holdam comes to Dresser from Laboratory For Electronics, Boston, Mass., where he was a vice president and in an earlier association had been a co-founder. He has also been a vice president of Tracerlab, Inc., Boston, Mass., where his experience included the supervision of nuclear instrument and beta gauge engineering.

In announcing the new vice presidential position, Mallon stated that Holdam's activities would be primarily concerned with supervising HST and SIE divisions of the company.

—*mwj*—

### ELECTRONICS COMPANY FORMED

Organized by four engineers, Ronald B. Hirsch, Ira Goodman, Arnold Rubin, and Robert Gruber, a new company, RHG Electronics Laboratory, Inc., recently began the manufacture of its products. The products include rf and if amplifiers systems and components. The company is presently engaged in tunnel diode amplifier developments.

Mr. Hirsch, president of the new company, was formerly in charge of the Commercial Amplifier Department at Instruments for Industry, Inc. The other three founders were also formerly employed by IFL. Mr. Rubin and Mr. Goodman were supervising engineers in the R&D Department and Mr. Gruber was the production manager of the company.

The new company is engaged in R&D projects and consulting engineering services. A product line will eventually include nuvistor, tunnel diode and other new tube and semiconductor products.

—*mwj*—

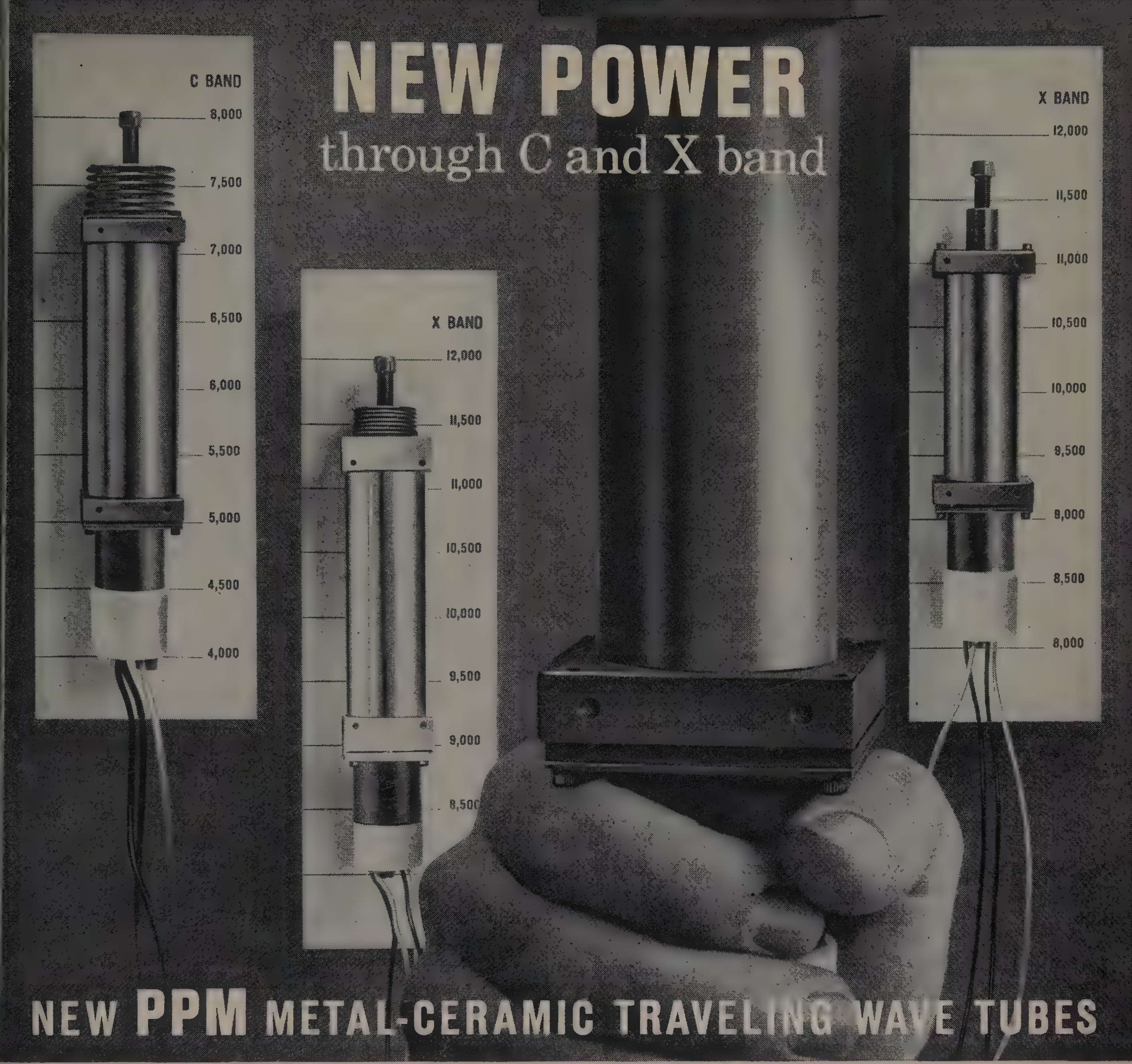
### IRE CANCELS TRANSMISSION SYMPOSIUM

The IRE has announced the cancellation of the International Symposium on the Transmission and Processing of Information which was to be held at the Massachusetts Institute of Technology, September 6-8, 1961. R. M. Fano, chairman of the organizing committee, stated that the Symposium had been cancelled because the response to the call for papers was inadequate for a program of length and character appropriate to an international symposium.

—*mwj*—

*(Continued on page 30)*

# NEW POWER
## through C and X band



## NEW **PPM** METAL-CERAMIC TRAVELING WAVE TUBES

Climaxing ITT's long history of pioneering in the traveling wave tube field are these new PPM types covering C and X bands and distinguished by the highest power output over the greatest bandwidths thus far available. The X-band TWT Type X-354 is rated at 5 watts CW from 8 to 12 kilomegacycles; the C-band TWT Type X-370 is rated at 10 watts CW from 4 to 8 kilomegacycles. Type X-368 serves as a driver for the X-354. As in other ITT traveling wave tubes, construction is exclusively metal and ceramic.

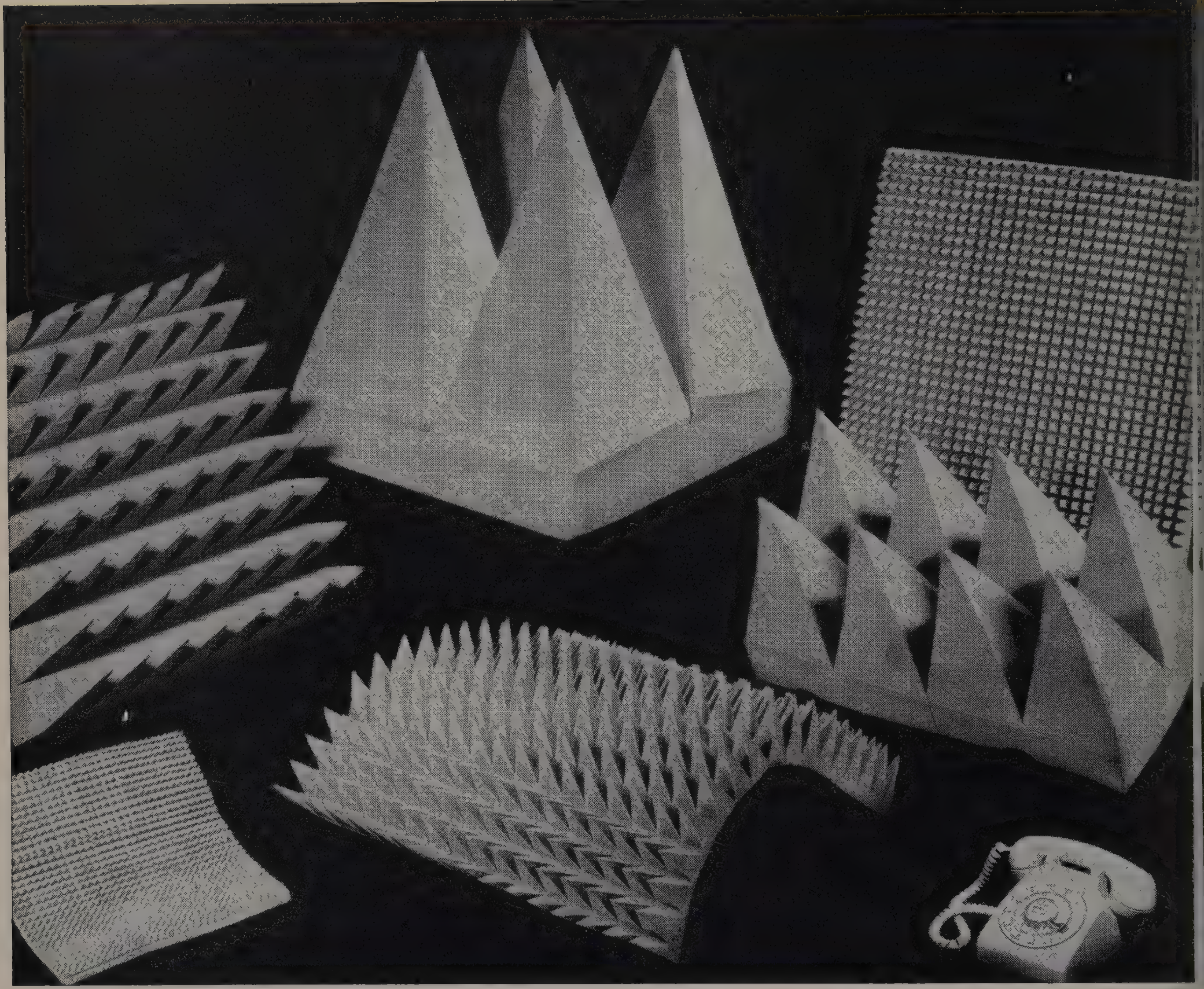
Power output and frequency coverage of this caliber result in a new standard of performance. For ECM requirements, frequency diversity radar or any other broadband microwave application, ITT has a complete line of S-band, C-band and X-band TWTs rated from .050 to 10 watts CW and to 1 kilowatt pulse output. ITT traveling wave tubes are available for immediate delivery and are backed by the world-wide resources and facilities of the ITT System.

ITT

*Write for information on the complete line of ITT traveling wave tubes. Application assistance is available for your specific requirements.*

**ELECTRON TUBE DEPARTMENT ■** COMPONENTS DIVISION
INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION, CLIFTON, NEW JERSEY

**ITT COMPONENTS DIVISION PRODUCTS:** POWER TUBES · IATRON STORAGE TUBES · HYDROGEN THYRATRONS · TRAVELING WAVE TUBES · SELENIUM RECTIFIERS · SILICON DIODES AND RECTIFIERS · TANTALUM CAPACITORS



# Absorbers take new shape to provide very high performance

**B.F.Goodrich "sharp-point" design improves testing reliability in anechoic chambers**

These newly-developed VHP (very high performance) broadband microwave absorbers can substantially improve the performance of anechoic chambers.

They can eliminate baffles yet provide chambers with lower reflection levels than previously existed. They can improve the performance of existing chambers by application to rear wall and/or center region. Their inherent high attenuations eliminate the need of additional metal shielding where moderate isolation is required. And because of Type VHP's excellent wide-angle absorption, chambers with reduced cross-section area can be used.

To take a specific example, Type VHP-18 at X band offers these outstanding electrical features.

- Reflection down by approximately 60 db for angles near normal incidence.
- Reflection down 40 to 50 db for both polarizations at angles of 60° to 65° from normal incidence (angles most often encountered in anechoic chamber sidewalls).
- Attenuation through the material in excess of 50 db.

B.F.Goodrich VHP absorbers are light, semi-flexible, easy to install. A variety of thicknesses, as shown in picture, enables the engineer to choose the desired absorption level and frequency range. If you would like more information on VHP absorbers, or want to know more about an entire line, just write *B.F.Goodrich Sponge Products, 130 Derby Place, Shelton, Conn.*

**MICROWAVE ABSORBERS BY B.F.Goodrich**

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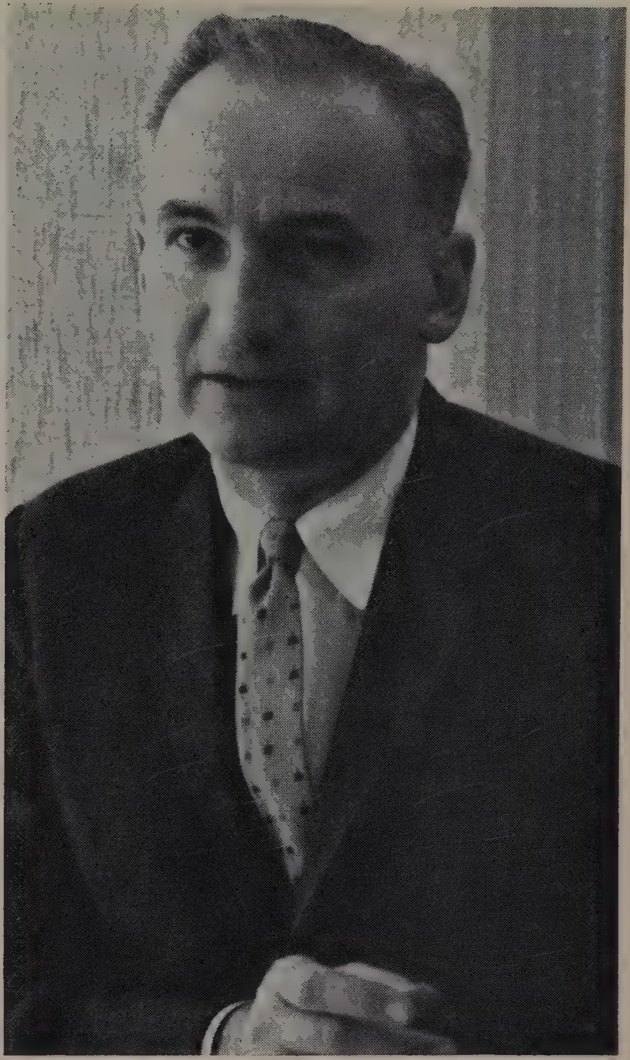
# DR. SIMON RAMO

*Executive Vice President*

THOMPSON RAMO WOOLDRIDGE

Canoga Park, California

By DAVID H. SIMON



In 1957, when his picture appeared on the cover of ime Magazine (an achievement rarer in the microwave dustry than Presidential citations), Dr. Simon Ramo, -founder of Ramo-Wooldridge and now Executive Vice resident of the $420 million Thompson Ramo Woold-dge, was recorded as saying, "When we started we hought that maybe, if we were greatly successful, we ight eventually have a staff of 150 people." The percep-ve Ramo has seldom been so far off base.

Incorporated in 1953, R-W was an outgrowth of the pectacular success at Hughes Aircraft of Ramo and Dr. ean E. Wooldridge. Though almost opposites in per-onality, these two formed a smooth-functioning team Hughes and managed to

- run two insignificant Air Force study programs at Hughes' tiny research lab up to an $8 million award for fire-control systems for the F-94;
- snare the Falcon missile award (due to an unusual guidance system proposal);
- capture the contract for the design of the F-102 navigation and fire control system, over stiff competition from 20 giants of the electronics and airframe industries.

These achievements, coupled with sole source awards Hughes for fire control systems for the entire inter-eptor program at the onset of the Korean conflict, gave ughes in 1950 what amounted to a near-monopoly on ajor Air Force electronics contracts.

During the next three years, a series of fundamental policy differences with the Hughes parent company management resulted in Ramo and Wooldridge leaving. At the time, Ramo was Vice President and Director of Operations, while Wooldridge was Vice President of the R&D lab.

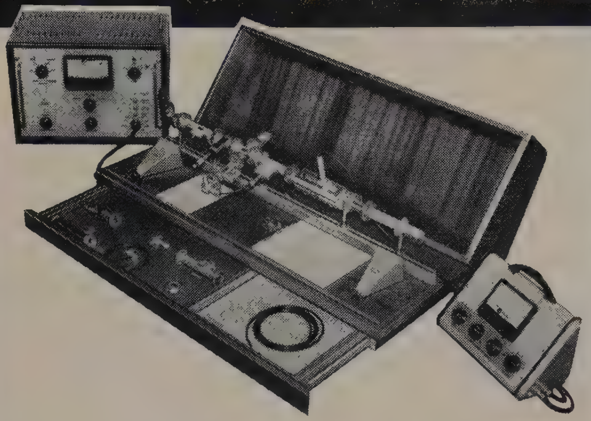
To keep the twosome intact the Ramo-Wooldridge Corporation was brought into being, this time with Wooldridge directing the operations as President, and Ramo heading up the technical aspects as Executive Vice President. Financial backing was provided almost immediately by Thompson Products, Inc., of Cleveland (in exchange for 49 per cent of the common stock, 87½ per cent of the preferred), and the new company set up shop in a one room office in Los Angeles, minutes away from the Hughes Culver City facility they had just forsaken.

Already aware of the capabilities of the R-W team, the Air Force lost no time in awarding them four classified study contracts, enabled the company to get into the black after only three months. Shortly afterward the Government decided that the forthcoming immense ICBM program required a totally new approach: a civilian company, working with the Air Force, and supervising all of the companies involved in the program. R-W was singled out as eminently capable of the task.

Under the skilled guidance of the steady Wooldridge

*(Continued on page 22)*

Sanders
BRITISH
MICROWAVE
IN THE U.S.A.



W. H. Sanders (Electronics) Ltd., a leading British supplier of microwave components and test equipment to the European electronics industry, now makes its precision equipment available to the American market. Traditional British craftsmanship coupled with a first class research and development organization, is presently producing a wide line of equipment and components for the bands 2.60-18.00Gc/s. Soon to be released are equipments and components for the bands 26.5-40 Gc/s. Research and development is also going forward in the millimetric bands.

Typical of the products at forward thinking Sanders is the Type 599 Microwave Educational Test Bench. This comprehensive set-up, specifically designed for University & Technical College teaching, comes fully equipped with Klystron Power Unit and transistorized selective amplifier. The waveguide bench, designed to operate between 8.2-12.V Gc/s contains a large selection of instruments & components likely to be met by the engineer in the microwave laboratory. To assist student & tutor, a handbook containing sections on microwave theory. Operation of each instrument & Component, and listing a number of practical experiments, is included with each assembly.

Through ..........................................................................................

American representatives to the Sanders Group of Companies, a nation wide network of engineering representatives is available to assist you with your requirements. Send for complete technical data on the 599 Microwave Educational Test Bench as well as other precision microwave components manufactured by W. H. Sanders (Electronics) Ltd. Many of the instruments are stocked in the U.S.A. for prompt delivery.

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Telex: Frankfurt 4-12970.

## RAMO

*(Continued from page 21)*

and the driving Ramo, the company's sales rang in at slightly below $30 million after just three years—with missile work responsible for only half the income. The remainder was brought in by a diverse product line which included airborne digital computers, missile test equipment, data-handling systems, and transistors (from subsidiary Pacific Semiconductors).

### Closer to Cleveland

Strapped for funds to underwrite the rapid expansion, Ramo and Wooldridge worked out a series of new deals with Thompson Products, each time relinquishing ownership of another piece of their brain factory.

By mid-1958, Thompson had acquired 58 per cent of the common stock, options on an additional 27 per cent, and the power to choose four of R-W's nine man Board of Directors, in exchange for $8½ million loaned to R-W. But the expansion rate was so great that even this wasn't enough. In its first four full years of operation the electronic whiz-kids had increased the company's sales twenty-fold (from $2 million at the end of 1954, to over $40 million at the end of 1957), and had acquired close to $30 million worth of assets. Responding to an attractive offer made by Thompson, the directors and employees of R-W agreed to sell the outstanding shares, merge completely with Thompson, forming Thompson Ramo Wooldridge Inc. Wooldridge became President, Ramo, Executive Vice President of a company with assets seven times as great as R-W's.

### The Early Days

The son of a Salt Lake City store owner, Ramo was born May 7, 1913, just 23 days before Wooldridge. Showing an academic flair from the start, he skipped grades in grammar school, breezed through high school with top marks. At the University of Utah his boundless energy and sharp mind won him membership in a half-dozen honorary and professional societies including Tau Beta Pi and Sigma Xi. It also won him a BS degree with highest honors. As a graduate student at the California Institute of Technology he first met Wooldridge, and both received PhD's at the age of 23. Ramo's was awarded magna cum laude for high grades in his courses, and an outstanding thesis on million-volt measurement techniques.

With Doctorate in hand, Ramo headed for an interview with GE in Syracuse. He got the job, but he claims to have won it on the basis of music, not brain power. A polished violinist with sufficient talent for a brilliant musical career, Ramo says he was hired by a civic-minded GE executive, to fill a vacancy in the part-time symphony orchestra in near-by Schenectady. In any case, he joined GE's research staff, soon found himself fascinated by the "mysterious" field of microwaves.

It seemed curious, particularly from a physicist's vantage point, that some of the basic laws of electricity appeared invalid at microwave frequencies. He began to write notes to himself: "What makes waves go down the inside of a hollow conducting pipe at high frequency but not at low frequency?" "How is it that high-frequency

*(Continued on page 24)*

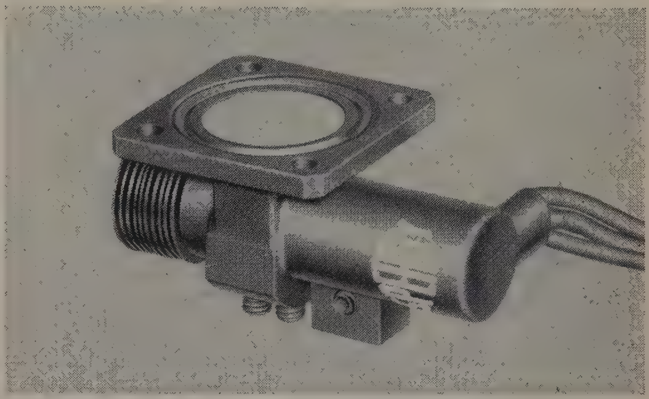
**another**
**microwave memo** *from* **SPERRY** ELECTRONIC TUBE DIVISION

# Announcing 30-Day Delivery on U Band, Two-Cavity Oscillators For Parametric Amplifier Pumping

Sperry Electronic Tube Division, Gainesville, Florida, announces an *immediate* solution to the drive source problems which have plagued developers of parametric amplifiers for some time. Now Sperry can deliver a U band, two-cavity klystron oscillator in just 30 days.

Fast delivery is possible because development work is completed on all tubes within the frequency and power output parameters described below. Soundness of the development work is already proved, since tubes of this type have been operating in several systems for some time.

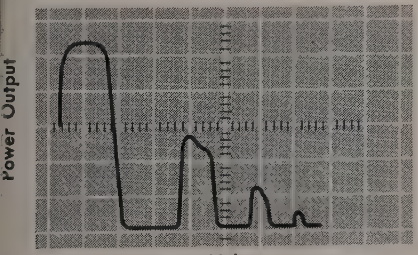
Sperry has developed a whole family of these oscillators. They cover the entire U band, and deliver output powers from 200 mW to 1.5 W.



## APPLICATIONS

All tubes in the new Sperry family operate with a characteristic flat-top mode. This constant relationship between beam voltage and output power makes tubes in the series particularly suited for driving parametric amplifiers, and for use in doppler radars and FM communication systems.

One important benefit of the flat-top mode characteristic is the availability of frequency modulation with very low incidental amplitude modulation. This inherent amplitude stability, together with high power output levels, makes the new oscillator family particularly useful for parametric amplifier applications. The same characteristics contribute to the desirability of these tubes for use in doppler radars and FM communication systems.



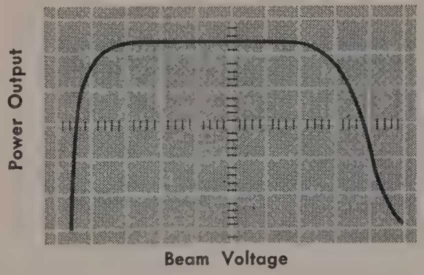
Typical mode shapes of two-cavity oscillator.

## RATINGS

Two-cavity oscillators in the Sperry series completely blanket the 12.5 to 18 kMc frequency range covered by the U band. The "family" of tubes is divided into two branches, one ranging from 12.5 to 15.5 kMc, and the other covering the 15.5 to 18 kMc area.

Output power ranges from 200 mW to 1.5 W in the lower frequency group, and from 200 mW to 1 W at the higher frequencies.

If optimum tuned, rather than flat-top mode operation is desired, power output may be increased 25%.



A typical main mode, adjusted for optimum flat-top operation.

## INHERENT BENEFITS

Tubes in the new Sperry family enjoy all the inherent benefits of two-cavity klystron design. These include precision tuning, high stability, amazing ruggedness and unusual stability at high output levels.

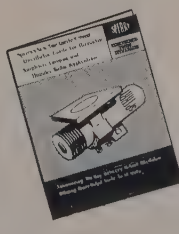
The series incorporates two design features which result in significant size and weight savings.

1. Electrostatic focusing, eleminating the heavy focusing magnets required in many designs.
2. A unique fixed-tuned design, in which the cavities are pressed into a configuration which delivers the customer's specified frequency.

All the tubes in this series show efficiencies in the area of 3.4% with the flat-top mode, and all have low levels of vibration-induced AM and FM noise.

## PRICE AND AVAILABILITY

At power output levels from 0.2 to 0.5 watts, tubes in the new Sperry family are priced at $2,295 each. With output from .5 to 1.5 watts, the price is $2,795 each. Tubes will be tuned to your specified center frequency, and they will deliver your specified power output level. All oscillators in this U band series will be shipped within thirty days of receipt of order.



**WRITE FOR SPERRY'S NEW BROCHURE** which describes the new U band oscillator family in greater detail. For the brochure, or for application assistance and quotation, contact:

**R. F. Forlaw,** Section 601
**Sperry Electronic Tube Division**
**Sperry Rand Corporation , Gainesville, Fla.**

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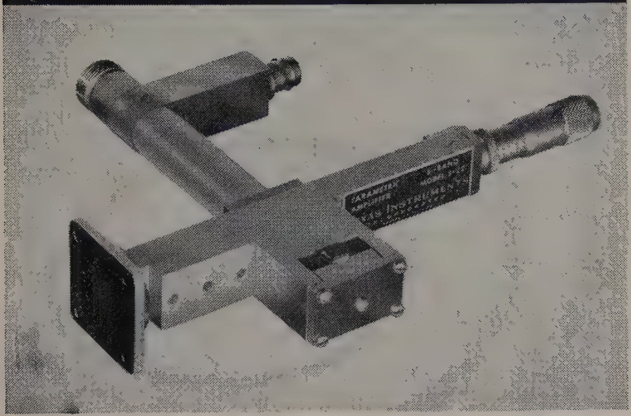


FOR MILITARY ENVIRONMENTS!

**Broadband parametric amplifiers** for applications at L, S, C, and X band are available now from Texas Instruments. The S-band model, designed with a TI XD-500 gallium arsenide diode, gives bandwidths up to 75 mc at 15 db gain. Gain variation is no greater than 3 db over temperatures ranging from −40°C to +50°C, and the unit meets the vibration requirements of MIL-E-5400D. Noise figure, including circulator loss is 3 db. The associated circulator is a miniaturized, three-port ferrite unit with 0.5 db insertion loss and 20 db isolation.

| TYPICAL MODEL S-22 SERIES SPECIFICATIONS | |
|---|---|
| **frequency** | 2.8 to 2.96 Gc |
| **bandwidth** | 40 mc |
| **gain** | 15 db |
| **noise figure** (includes circulator loss) | 3 db |
| **pump frequency** | X band |
| **diode** | Texas Instruments XD-500 $F_c \geqq 70$ kmc at −2v bias |
| **temperature range** | −40°C to + 50°C |
| **vibration** | per MIL-E-5400D |
| **pump power** | 50 mw |

For details on TI's S-band amplifiers, write for Bulletin No. DLA-1217. For information on specific applications at all frequencies, contact MARKETING DEPARTMENT.

TEXAS INSTRUMENTS
INCORPORATED
APPARATUS DIVISION
P. O. BOX 6015
DALLAS 22, TEXAS

## RAMO

*(Continued from page 22)*

current can be drawn from electrodes of an electronic tube when the electron current in the tube doesn't even flow to those electrodes?" "May we still speak of impedance at Microwave frequencies?"

When he began to solve the puzzle, he developed into one of GE's—and the country's—answer men in the new field. In the early '40's GE sent Ramo on a barn-storming lecture tour with a two-hour talk on electrical concepts at high frequencies. Electronics Magazine heard it, liked it, printed it. The book-publishing side of McGraw-Hill got wind of it, decided they liked it too, talked Ramo into expanding it into a book. Published in 1943, *Introduction to Microwaves* was one of the first attempts to provide a non-mathematical unmasking of microwave principles. Containing "some important points in a more or less orderly fashion," the chapter titles, like those of *Tale of Two Cities* are complete sentences: "Microwaves Are Very Different from Lower Frequency Electricity", "Microwaves Practically Do Not Penetrate Metal", "All Conducting and Dielectric Boundaries Are Wave Guides."

The following year, largely through the efforts of John Whinnery (then a GE associate of Ramo's; now Dean of Engineering, UC-Berkeley), a greatly expanded version was published under the title *Fields and Waves in Modern Radio*. Originally intended for microwave specialists, the basic concepts are so lucidly explained that the 18 year old text is being used at over 100 colleges, at levels as low as senior, and even junior, year. Translated into a half-dozen languages including Russian (for which the authors are given credit but no royalties), the book earns more money for Ramo and Whinnery now than it did in its first year.

While the book was in the formulative stages, Ramo hammered away at the traveling-wave principle to get away from transit time problems. He formulated the idea of a rotating space charge to provide a chance for multiple whacks at the electrons, noted that this answered the enigma of the operation of magnetrons. Using the high-voltage know-how from his thesis, he built the country's first pulsed magnetron, proudly announced its ten per cent efficiency, found the British had achieved this and more, shifted his attention to receivers and cavity resonators. (His pioneering work on resonators enabled GE to get the basic patents.)

But after ten years of abstract physics at GE, Ramo had reached saturation and craved programs with practical applications. During a 1946 trip to California he was invited to join Hughes Aircraft's ten man electronics group as research director. He accepted and thus launched the highly successful but ill-fated Hughes saga.

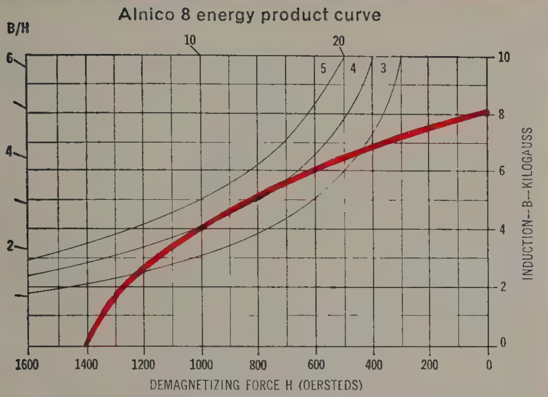
### No Formula for Success

In large measure, Ramo's spectacular rise in a dozen years from GE section head to top corporate executive may be attributed to a lightning-fast mind, which, as one of his associates expressed it, "combines all the best elements of a computer and a diplomat." The result: an impulsive, incisive, yet considerate manner. "You can't fool him. He'll catch an error before you're through making it. But by the time you've finished the discussion, he's got you

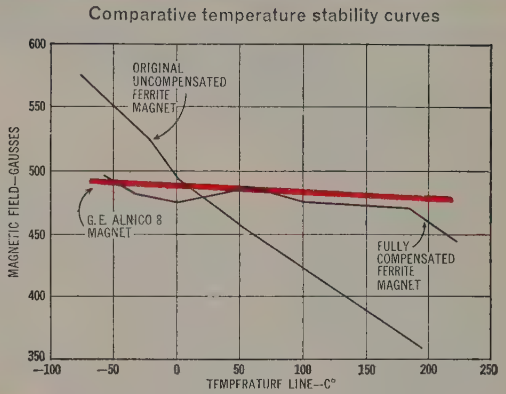
*(Continued on page 26)*

*How G.E. Alnico 8 permanent magnets can help you*

# DESIGN MORE COMPACT TWT PACKAGES!

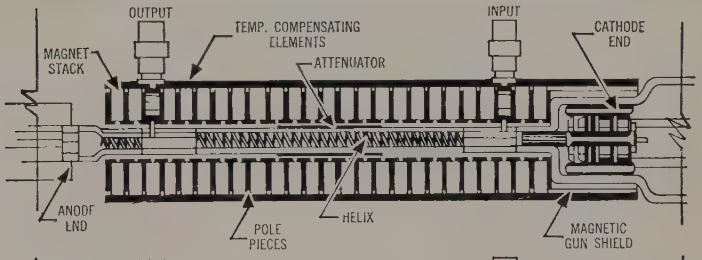


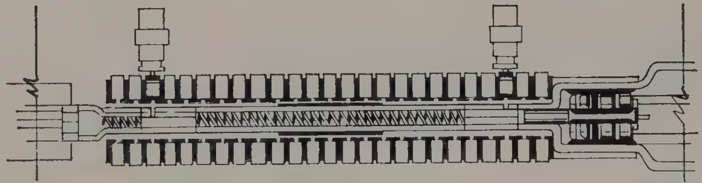
① **HIGH ENERGY PRODUCT**—Alnico 8 by G-E, Edmore represents a significant breakthrough in permanent magnet materials. The design engineer now has at his disposal a material of high coercive force (1400), high energy product (4 x $10^6$ gauss-oersteds), excellent temperature stability, and economical cost.



② **LOW IRREVERSIBLE TEMPERATURE LOSS** — Only .6 of 1% from 20°C. to —193°C. Either of these factors alone will reduce the amount of "over-design" required in a permanent magnet for a given performance in a traveling wave package. Together, they can effect important economies without impairing performance.

③ **EXTREMELY LOW REVERSIBLE TEMPERATURE COEFFICIENT**— Only 0.013%/°C. This represents a stability up to 15 times greater than that of barium-ferrite materials and means that temperature compensating elements on magnet stacks can be completely eliminated.





Approximate reduction in size with Alnico 8 magnet stack

In these three ways, then, G-E Alnico 8 eliminates expensive design time for compensators, saves costs of material, fabricating and assembly — and lets you design compact, high-performance TWT packages at lower cost.

**There's more!** To see how Alnico 8 by G-E, Edmore fits your specific requirements, send for full information today. Request Product Engineering Data 1108 and 1109. A letter or phone call will do fine. Or we would be pleased to have you visit us here:

Magnetic Materials Section, General Electric Company, 7854 N. Neff Lane, Edmore, Michigan. In Canada, contact Canadian General Electric Company, 940 Lansdowne Avenue, Toronto 4, Ontario.

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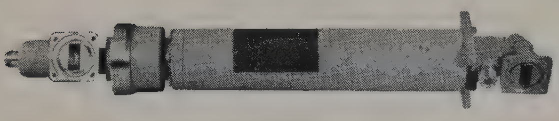

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## RAMO

(Continued from page 24)

believing you caught the error and corrected it yourself."

Ramo's explanation is different. "I was never trying to succeed, per se, either as a scientist or an executive. I just devoted myself to areas in which I was interested, and where there seemed to be a need." There *is* no general rule for success, he points out, but it's easier to be successful if you're competent, fair, and respected by others—and if you have a little luck. "I found there was a need for people who could integrate technical and non-technical problems, and who could communicate." Ramo could and did.

Another enraptured TRW executive comments, "Si is one of a new breed who will have a hand in running the country in the future—the scientist-executive, who understands the technical mind and personality, and business, industry and marketing." Ramo agrees that there is a clear and increasing need for the technical executive, "but," he says, "just because we're entering a more highly technological era doesn't mean the top men will necessarily be scientists. There will always be a need for high level sales, legal and financial executives."

### Intellectronics

Today, one of Ramo's favorite subjects is "intellectronics," a term Ramo made up three years ago to refer to the extension of the intellect by electronics. Dr. Ramo explains what it's all about by saying, "The rest of this century will see the gross extending of the human intellect and senses by application of science and technology. In every intellectual pursuit in which man is engaged, be it in the professions, in production, in military command, in teaching—everywhere—when we analyze what we do with our minds, we find a part that is best assigned to electronic machines. Reduce the intellectual activity to stored and incoming information, to logical processes, sorting, deciding; and the part that is well understood, that involves rates and quantities too large for the human mind, assign to the machine. This frees the human intellect for the more complex aspects of the intellectual task, above the routine work of the electronic partner.

"The human brain consists of the equivalent of perhaps ten billion electron tubes or transistors in a cleverly flexible and reliable, interconnected array. The human mental apparatus is a million times more brilliant intellectually than any machine that has so far been built or even conceived. Clearly, such a versatile intellectual capacity should not be applied to tasks that do not require it and that are satisfied by a relatively stupid intellectual machine that specializes."

Law, medicine, language, education, banking will all be altered by intellectronics, Ramo points out. "Consider the practice of law. Two or three decades from now it might be possible for an attorney, using a typewriter-like device, to query a huge national central repository and have the intellectronics system scan, select, and present on a viewing screen in a few seconds the equivalent results of dozens of trained searchers covering many decades of records over the entire nation.

"The concept of what language is will probably change drastically, since our machine partners will create pressure for a universal, purely informational, completely logical and consistent kind of language. And an intellectronics

r. Ramo (left) shows Dr. Wooldridge the Paul T. Johns ophy "for outstanding contributions to Aeronautics and As- nautics" presented by the Air Force Association's Arnold Air ciety in recognition of Dr. Ramo's role in the Air Force At- s, Thor, Titan and Minuteman programs as the "prime chitect of the nation's ballistic missile arsenal."

stem could make a tenfold change in the effectiveness education, speeding up, adding explanations, skipping eps as appropriate, thereby stimulating the thinking of e student."

Coins, currency, checks and even most bookkeeping cords may become extinct, Ramo predicts. "If you buy necktie or a house, your thumb before an electronic anner will identify you, and a nation-wide network ill debit your account and credit the seller." But there ill be pitfalls, he warns. "Occasionally, a transistor burn- g out in Kansas City may accidentally wipe out some- e's fortune in Philadelphia."

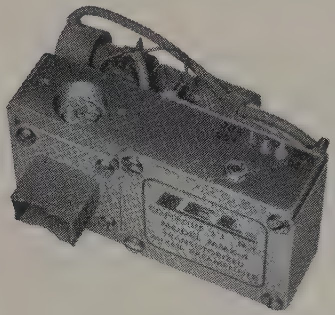
But as Ramo sees it, the real bottleneck to progress, to safe, orderly and happy transition to the coming tech- ological age, lies in the severe disparity between scien- fic and sociological advance. "Will technology, properly sed, make possible a correction of the very imbalance hich causes technology to be in the lead? The challeng- g intellectual task of accelerating social progress is for e human mind and not his less intellectual electronic artner, but if the machines do more of the routine, veryday intellectual tasks and insure the success of the aterial operations of the world, man's work will be evated to the higher mental domains. He will have e time, the intellectual stature, and hence the inclina- on to solve the world's social problems. We must be- eve he has the capability."

LOW NOISE

**for C Band**

The CBH, CCH, CDH, and CEH Series of Integrated Waveguide Mixer-Preamplifiers.

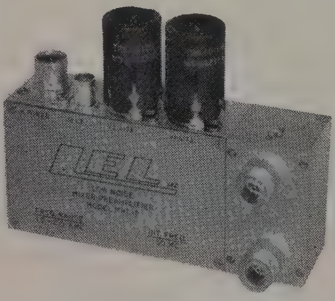
Noise Figure: 7.5db



**for X Band**

The XAH, XBH, XCH, and XDH Series of Integrated Microwave Mixer-Preamplifiers.

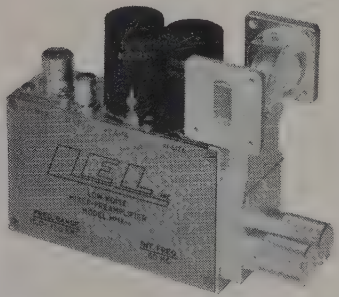
Noise Figure: 7.5db



**for L, S and C Bands**

The LAC, SAC, SBC, and CAC Series of Coaxial Mixer-Preamplifiers.

Noise Figure: 7.5db



**for KA and KU Bands**

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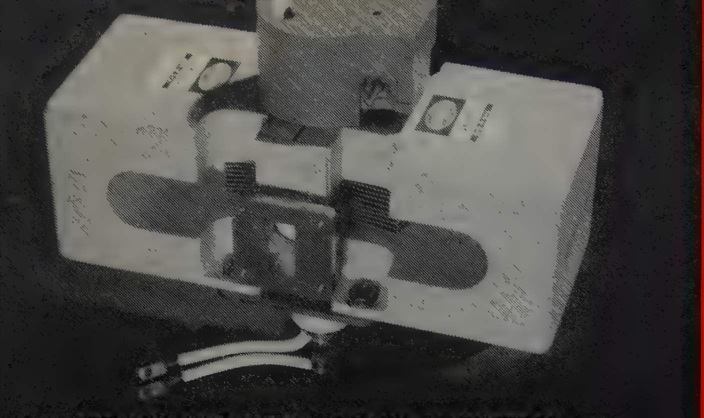

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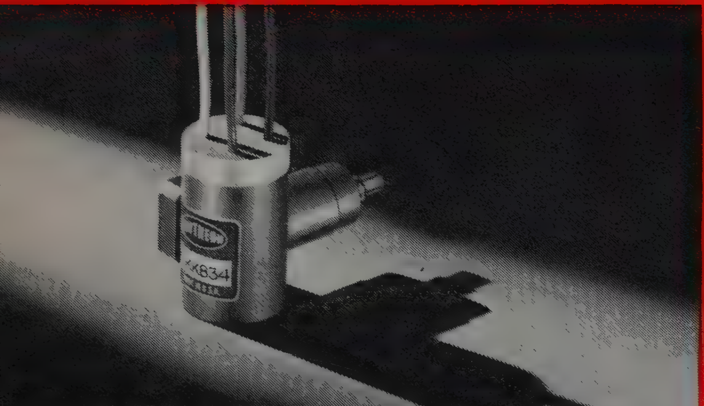
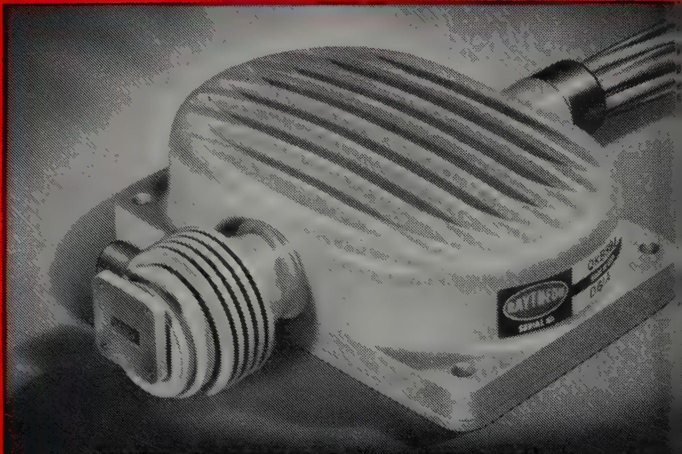
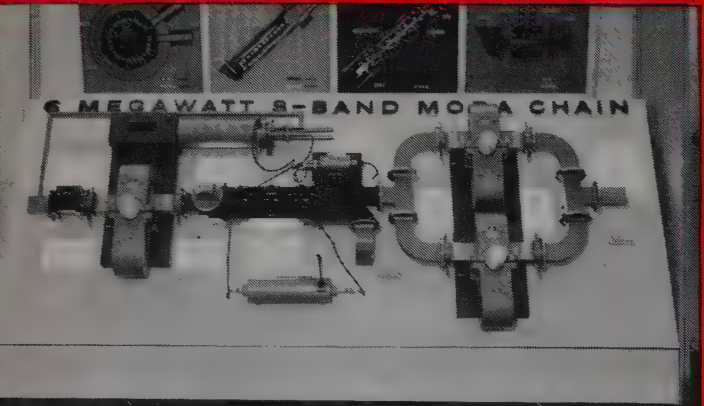


EXTREMELY RUGGED K-BAND KLYSTRONS have very low microphonics, excellent thermal stability. QKK 923 for 23.5-24.5 and QKK 834 for 34.0-35.6 kMc.



NEWEST ELECTRONICALLY TUNED BWO's have 40 m
minimum power output; are half the size and weight
their predecessors. QKB 890 for 12.4-18 and QKB 89
for 18-26.5 kMc.



PHASE STABILITY AND HIGH EFFICIENCY are features of Raytheon designed high-power amplifier chains for sophisticated search and track radar applications. Chain shown is one example of Raytheon's ability to supply microwave tubes, ferrite devices and magnetic components in a completely integrated package.

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- Experimental X-band high-ambient-temperature magnetron, QR 933
- Reflex klystron that extends millimeter band coverage to 120 kMc, QKK 971
- Rugged miniature magnetron for missile beacon transponders, QKH 821

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# RAYTHEON at WESCON puts emphasis on AEROSPACE MICROWAVE TUBES

Raytheon has been moving fast to break the bottleneck in the development and production of new microwave tubes for aerospace systems. WESCON engineers will see the evidence of this as a variety of new tubes for airborne, space and missile applications are introduced at WESCON.

Whether or not you plan to visit San Francisco, you'll want to skim the opposite page for tubes that will answer your aerospace systems needs . . . then let us know where to send the appropriate information bulletins.

*See us at WESCON—Booth 3410-3412*

WRITE TODAY, SPECIFYING TUBES that interest you, or tell us about your particular microwave problem. Address Microwave and Power Tube Division, Raytheon Company, Waltham 54, Massachusetts. In Canada: Waterloo, Ontario.

RAYTHEON

**RAYTHEON COMPANY**

MICROWAVE AND POWER TUBE DIVISION

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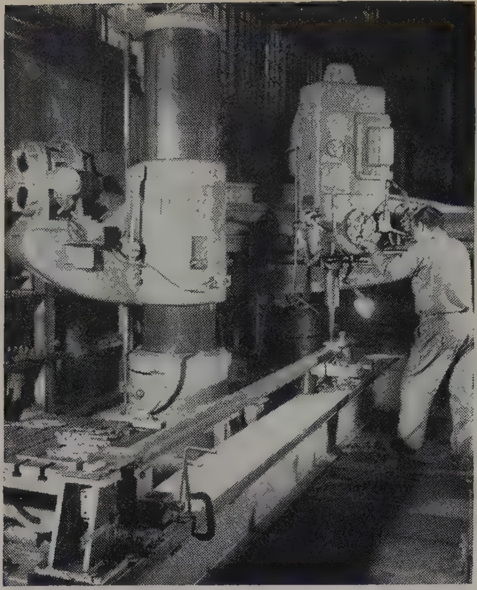

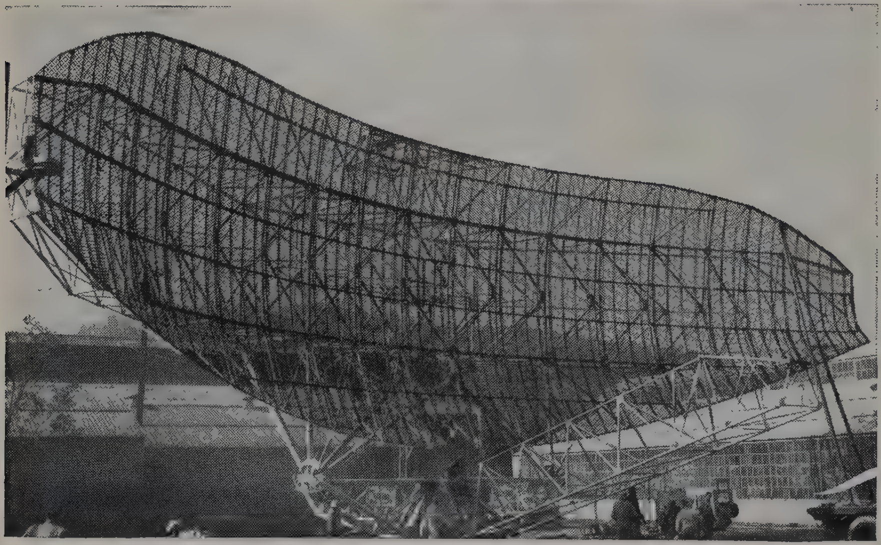

**SKILL HERE MEANS ACCURACY HERE**

U.S.A.F.'s FPS-35 Radar Antenna, built for Sperry Gyroscope Co.

Blaw-Knox skill in fabricating intricate structures to close tolerances makes possible even greater accuracy in the operation of radar antennas, tracking antennas or radio telescopes. Highly developed manual skills and skillful operation of machine tools assure better fit in these large, but extremely precise instruments.

It is the master-craftsman skills at Blaw-Knox, plus Blaw-Knox's unique shop facilities and years of fabricating experience, that produce close-tolerance instruments. And Blaw-Knox engineering skills assure the right design to make the best use of those facilities and that experience.

Blaw-Knox designs and produces antennas to close tolerances with minimum deflections at reasonable cost — fabricates in steel, special alloys and aluminum — designs to your needs or builds to your specifications. Complete research, engineering, testing and fabricating facilities are at your disposal. Write or phone for immediate attention. Blaw-Knox Company, Pittsburgh 38, Pennsylvania. Phone STerling 1-2700.

**BLAW-KNOX**
*ANTENNAS*

BLAW-KNOX

Blaw-Knox designs and manufactures for America's growth industries: METALS: Rolling Mills • Steel Processing Lines • Rolls • Castings • Open Hearth Specialties • PROCESSING: Process Design, Engineering and Plant Construction Services • Process Equipment and Pressure Piping • CONSTRUCTION: Concrete and Bituminous Paving Machines • Concrete Batching Plants and Forms Gratings • AEROSPACE: Fixed and Steerable Antennas • Radio Telescopes Towers and Special Structures • POWER: Power Plant Specialties and Valves

Circle Reader Service Card 21

## Industry News

*(Continued from page 18)*

### WUNSCH JOINS MOTOROLA MILITARY ELECTRONICS DIVISIO

David E. Wunsch has joined the mi tary electronics division of Motorola C Chicago, Ill., as a staff engineer for the Radar Development Department.

Mr. Wunsch has been an engineer on the microwave communication advanced planning staff at the Collins Radio Co., Dallas, Tex. and has served as a radar ground support system designer at General Ele tric LMED, Johnson City, N. Y.

A member of the IRE, PGAP an PGMTT, Mr. Wunsch received his BSE from the University of Houston in 19 and his MSEE from Southern Methodi University in 1961.

—*mwj*—

### PALMER APPOINTED DIRECTOR RESEARCH AT HUGGINS

Dr. James L. Palmer has been appoint to the staff of the Research and Develo ment Departme at Huggins Labor tories, Inc., Sunn vale, Cal., as dire tor of research. Previously, D Palmer was en ployed as enginee ing manager f traveling wa tubes at Litto Industries Electr Tube Division, S Carlos, Cal. He is the author of sever papers on electron beam theory.

In his new position at Huggins Labor tories, Dr. Palmer will be in charge planning, administration, and technic direction of all R&D activities, includi projects dealing with lowering of noi figures, refinement of focusing method extension of frequency coverage and tu life, and increase of gain and power ou put.

Immediate developmental work scheduled for high power, high efficienc light weight helix-type traveling wav tubes meeting the extreme environmen of airborne, missile, and space applic tions.

—*mwj*—

*(Continued on page 32)*

TWO New COMPLETE LINES

# TWT AMPLIFIERS

## LOW POWER  MEDIUM POWER

UTILIZING

## PERMANENT MAGNET FOCUSED TRAVELING WAVE TUBES

### LOW POWER AMPLIFIERS

| Model Number | T603 | T604 | T605 | T606 |
|---|---|---|---|---|
| Frequency Gc | 1-2 | 2-4 | 4-8 | 8-12 |
| Min. Power Out MW | 15 | 10 | 10 | 5 |
| Min. Small Sig. Gain db | 35 | 35 | 35 | 35 |

### MEDIUM POWER AMPLIFIERS

| Model Number | T607 | T608 | T609 | T610 |
|---|---|---|---|---|
| Frequency Gc | 1-2 | 2-4 | 4-8 | 8-12 |
| Min. Power Out Watts | 1 | 1 | 1 | 1 |
| Min. Small Sig. Gain db | 30 | 30 | 30 | 30 |

TYPICAL POWER OUTPUT EXCEEDS GUARANTEED VALUES BY OVER 2 TO 1
SHORT AND OPEN CIRCUIT STABLE • IDEAL FOR TEST EQUIPMENT APPLICATIONS.
STABLE OPERATION — NO OSCILLATIONS

Ruggedly built — for long service under rough conditions • Heavy gauge aluminum construction • 3 separate meters — beam current, beam voltage and grid voltage simultaneously measured • Overcurrent protection — safety interlocks • Permanent magnet focusing on all tubes — no need for heavy solenoids or solenoid power supplies resulting in lightweight, ruggedness, reduced heat dissipation — eliminating the necessity of tube alignment and thus the danger of destroying the tube • CW or pulsed operation • Capable of being pulsed and AM modulated • Available in bench cabinet or supplied for rack mounting.

Long Life Tubes—Full guarantee for 6 months or 500 hours then prorated for second 6 months or 500 hours. Typical tube life greatly exceeds warranty.

## EXTREMELY BROADBAND MEDIUM POWER AMPLIFIERS

**MODEL T601**
**2—16 Gc**
Over 1 watt output over most of range. Over 60 db gain in center of band. 2nd harmonic conversion gain as high as 23 db.

**MODEL T602**
**10—20 Gc**
Over 2 watts output over most of range. Over 35 db. gain over most of band.

WESCON SHOW
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AMER. ELECT. LABS., INC.

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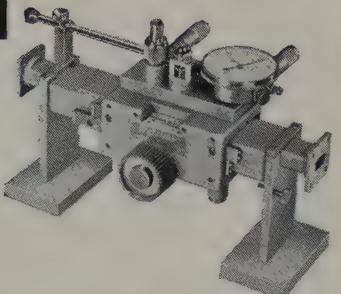
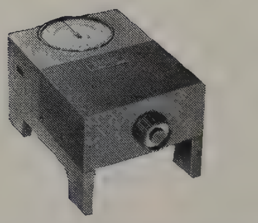
**Precision Measurement Demands**

**QUALITY MICROWAVE**

**instruments**

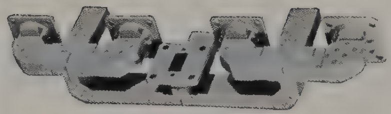
- ATTENUATORS
- SLOTTED LINES
- WAVEGUIDE COUPLERS
- TERMINATIONS
- FREQUENCY METERS
- PHASE SHIFTERS
- DETECTOR MOUNTS
- PRECISION TUNERS
- NOISE SOURCES
- TRANSITIONS
- GAIN HORNS
- WAVEGUIDE SWITCHES

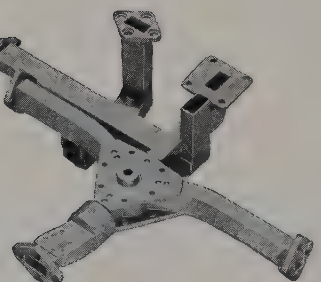




**and components**

- MIXERS
- FILTERS
- ANTENNAS
- DIRECTIONAL COUPLERS
- WAVEGUIDE TEES
- DETECTOR MOUNTS
- DELAY LINES
- HYBRIDS
- POWER DIVIDERS
- COMPLEX BENDS
- MODULATORS
- PRESELECTORS





Consult Waveline in order to achieve maximum compliance with your complex waveguide requirements. Standard instruments and special components are available.

**WAVELINE INC.**

CALDWELL, NEW JERSEY

Phone: CApital 6-9100 TWX Caldwell, N. J. 703

*(Continued from page 30)*

### DORNE AND MARGOLIN APPOINTS MALECH ADVANCED ANTENNA CHIEF

Robert Malech has been appointed head of the Advanced Antenna Development Section of Dorne & Margolin, Inc., Westbury, N. Y., it was announced by Arthur Dorne, president of the company.

In his new capacity Mr. Malech will be responsible for the development of new basic approaches for antenna systems and components. He was formerly head of the Microwave Systems Group and senior project member at Radio Corporation of America, serving as consultant to RCA facilities at Camden and Moorestown, N. J. (BMEWS). He was responsible for group development of thick-walled radomes, monopulse radars and supergain antennas.

Mr. Malech graduated from City College of New York in 1954 and received his MEE degree at Polytechnic Institute of Brooklyn. His predoctorate studies were conducted at Boston University.

—*mwj*—

### HEWLETT-PACKARD ANNOUNCES EXPANSION OF EUROPEAN OPERATIONS

Hewlett-Packard Co., Palo Alto, Cal., has announced a major expansion of its European operations, including the leasing of a manufacturing facility in England and the construction of a new plant in West Germany.

The announcement, made by President David Packard, came less than a month after the company, a major manufacturer of electronic measuring instruments, had announced that it will build a new plant in Loveland, Colo.

The new plant, situated in Bedford, England, includes two buildings totaling 27,700 square feet and will be operated by a newly-formed subsidiary company, Hewlett-Packard, Ltd. The firm's managing director is John M. Cage, formerly director of development for the parent company.

Production operations at Bedford will begin in September. While initial emphasis will be on manufacturing, the company plans to set up a product development department which will be staffed with several British engineers and scientists.

—*mwj*—

*(Continued on page 34)*

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# MICROWAVE DEVICE NEWS from SYLVANIA

**50%**
**SMALLER!**

**75%**
**LIGHTER!**

## Low Cost, High Performance

# PPM-FOCUSED TWT's

## for operation from 1 to 12Gc

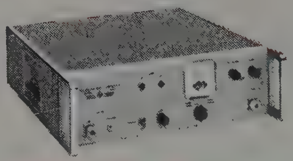
Now available from Sylvania—a new family of traveling wave tubes designed for high-performance microwave amplifier applications where economy, compactness, light weight are vital design considerations.

Less than 4 lbs. in weight and 2¼″ in maximum diameter, these TWT's present unusual opportunities for compact design of such end-products as microwave test equipment. No electrical performance is sacrificed in attaining these advantages over bulky, 12-16 lb. solenoid types. In addition, they are priced at less than $1,000 each in quantity.

For further information contact your nearest Sylvania Sales Engineering Office, or write Electronic Tubes Division, Sylvania Electric Products Inc., 1100 Main St., Buffalo 9, N.Y.

| Frequency Range (Gc) | Sylvania Type | Power Output | Min. Gain (db) |
|---|---|---|---|
| 1-2 | TW-4267 | 15mW | 35** |
| 1-2 | TW-4268 | 1W | 30* |
| 2-4 | TW-4261 | 10mW | 35** |
| 2-4 | TW-4260 | 1W | 30* |
| 4-8 | TW-4281 | 10mW | 35** |
| 4-8 | TW-4278 | 1W | 30* |
| 8-12 | TW-4282 | 5mW | 35** |
| 8-12 | TW-4273 | 1W | 30* |

**small signal gain *at saturation



**Hewlett-Packard specified Sylvania TWT's** in the new versatile 1-Watt amplifiers, Models 489A (1 to 2 Gc) and 491C (2 to 4 Gc).

**AT WESCON**—see the Sylvania exhibit, Booth #3201, 3, 5, 7, 9, 11, 12, 3302, 4, 6, 8, 10, 12

# SYLVANIA

SUBSIDIARY OF
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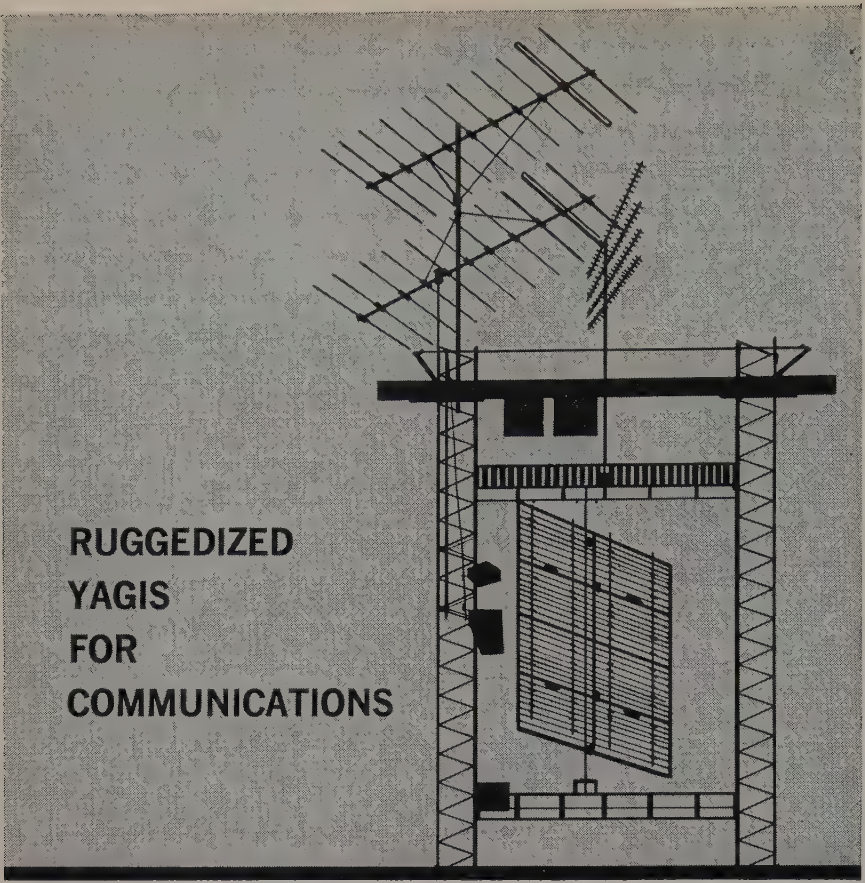

Super-strength, super performance yagis for all communications needs such as point-to-point radio, rebroadcast TV, and other modes of communications within the range of 30 mc to 500 mc. All welded, heavy aluminum construction that pays for itself after the first storm. These Taco ruggedized yagis feature low VSWR, vertical or horizontal mounting, multiple matched arrays, built-in coaxial feed, built-in balun, and a wide range of models and mounts.

This is the economical, dependable answer to commercial and military communications transmission and reception needs.

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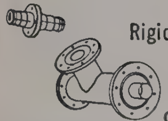
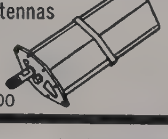
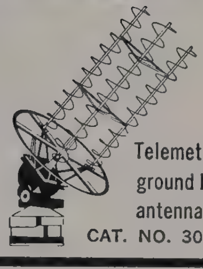
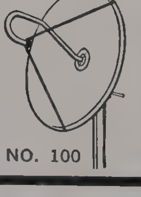
TACO PRODUCTS

Ruggedized yagis
CAT. NO. 600


Rigid transmission line
CAT. NO. 200


Airborne antennas
CAT. NO. 400


Telemetry and ground base antennas
CAT. NO. 300


Microwave antennas
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CAT. NO. 500
Large parabolics from 14′ to 32′.

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## Industry News

*(Continued from page 32)*

### DR. KOTIK APPOINTED VICE PRESIDENT OF TRG

Dr. Jack Kotik has been appointed vice president of Technical Research Group, Inc., Syosset, N. Y. He has been the company's treasurer since 1957, a position he will continue to hold.

TRG undertakes research and development projects in the microwave, electronics, applied physics, hydrodynamics, nuclear, and materials fields.

Dr. Kotik joined TRG in 1954 as head of the company's Mathematics and Radomes Department. Prior to that he was, for two years, associated with the MacMillan Laboratories, Ipswich, Mass., as senior scientist. At the same time, he also served as research assistant in the Harvard University Department of Mathematics.

Dr. Kotik is a graduate of Massachusetts Institute of Technology, with a PhD in Mathematics, and is a member of the American Mathematical Society, and the Society of Naval Architects and Marine Engineers.

—*mwj*—

### HAZELTINE DEVELOPING MOBILE GROUND RADAR SET

A mobile ground surveillance radar, capable of travelling on land and across water, is now being developed by Hazeltine Corp., Little Neck, N. Y., for the U. S Army. A modification of the shelter-housed AN/TPS-25, now operational with Army units, the mobile radar will detect and distinguish moving targets at 20,000 yards.

Under contract from the U. S. Army Signal Corps, the Hazeltine radar will be installed in an M-257 armored personnel carrier, a tracked amphibious vehicle which offers great mobility and protection for surveillance. The carrier can achieve speeds of 40 miles per hour on land and four miles per hour in water, and can be dropped by air into strategic areas.

A telescoping antenna mast will afford "quick-look" capability and long-range surveillance of moving targets. The radar can differentiate between a walking man and woman a mile away since a woman's steps are normally shorter and quicker. While this indicates its ultra-sensitivity, the basic purpose of the radar is to detect ground movement in combat areas in all weather and at all times.

The radar's audio presentation reveals the existence of moving targets and the nature of the targets. The steady whining sound produced when the radar signal is reflected from a moving vehicle is noticeably different from the sound produced when the radar signal is reflected from a moving man.

—*mwj*—

*(Continued on page 38)*

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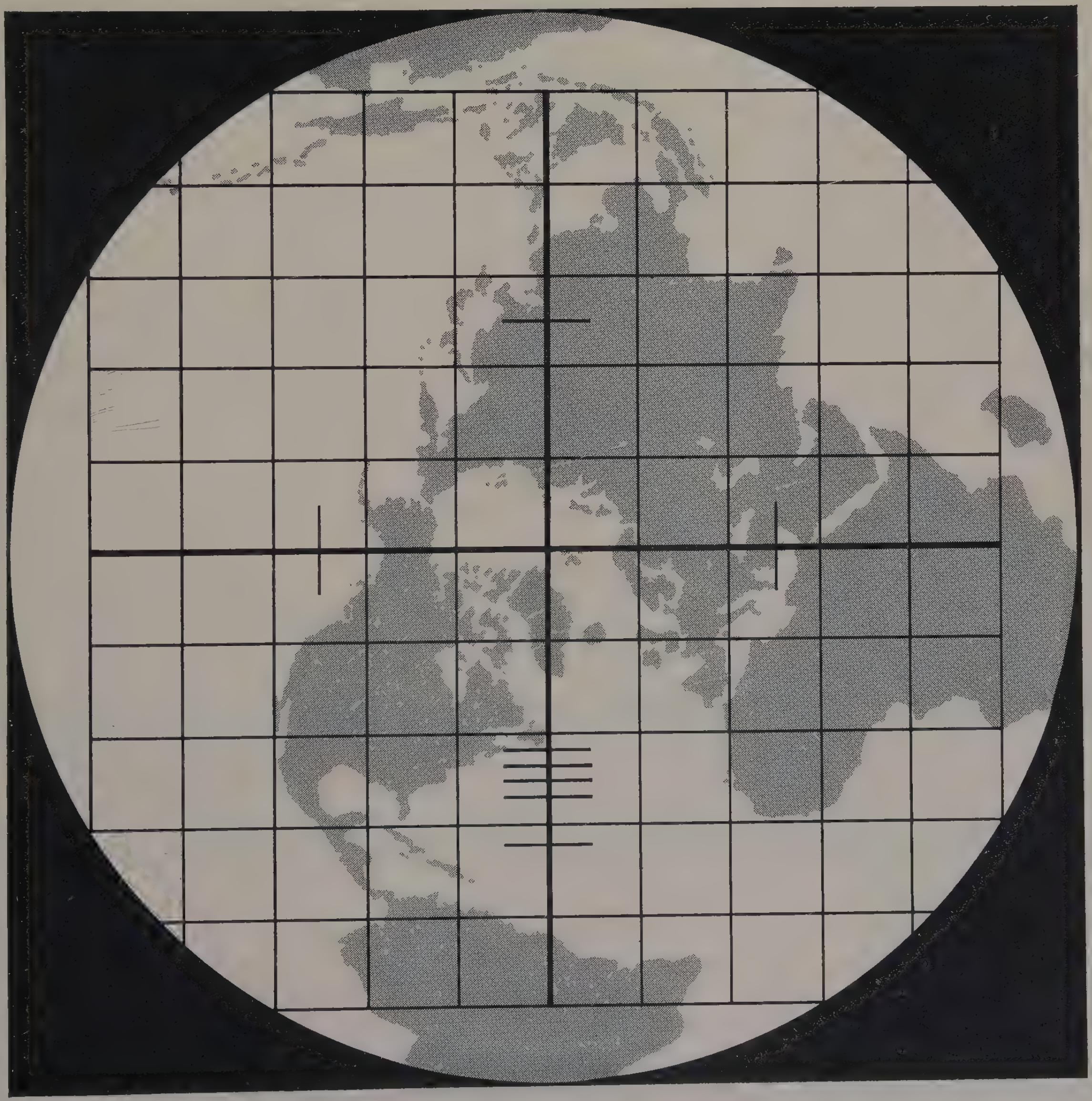
THERE'S A NEW AMERICAN MEMBER OF WORLDWIDE EMI

The name? EMI/US. Now with its own facilities for research, development, manufacturing and marketing in the U.S., EMI/US offers a complete range of electronics—from electron tubes and magnetic tape to broadcast equipment—for the industrial, military, broadcast and consumer markets. EMI/US is a part of one of the largest electronic companies in the world, with 53 years of pioneering achievements in electronic design and manufacture, more than 30 factories at key points around the globe. Production facilities in Los Angeles, sales representation throughout the U. S. Address inquiries to: EMI/US, 1750 N. Vine Street, Los Angeles 28, California.

EMI

Inquiries from outside the U.S.
—to EMI Electronics Ltd.,
Hayes, Middlesex, England.



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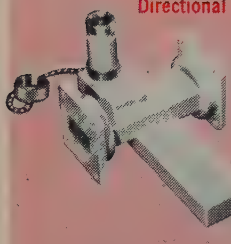
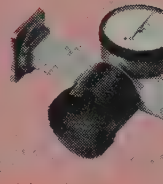
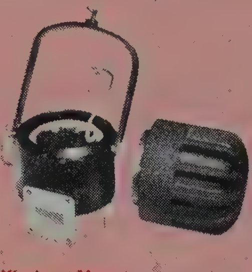
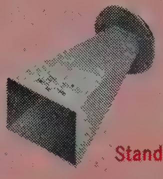
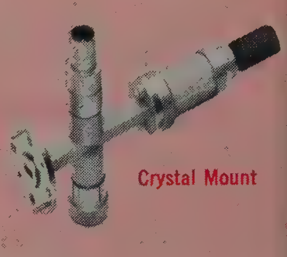
# ULTRAMICROWAVE®











| Size Designation<br>Frequency Band in KMC<br>Waveguide Nomenclature | DBW<br>90-140<br>RG-138/U | | DBA<br>60-90<br>RG-99/U | | DBB<br>50-75<br>RG-98/U | | DBC<br>33-50<br>RG-97/U | | DBD<br>26.5-40<br>RG-96/U | | DBE<br>18-26.5<br>RG-53/U | | DBF<br>12.4-18<br>RG-91/U | | DBG<br>8.2-12.4<br>RG-52/U | | DBH<br>7.05-10.0<br>RG-51/U | | DBJ<br>5.85-8.2<br>RG-50/U | | DBK<br>3.95-5.85<br>RG-49/U | | DBL<br>2.6-3.95<br>RG-48/U | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* |
| **Tube Mounts** | | | | | | | | | | | | | | | | | | | | | | | | |
| Klystron Tube Mount | | | | | | | | | | | DBE-111 | *$42* | | | DBG-111-1 | *$215* | DBH-111-1 | *$225* | DBJ-111-1 | *$260* | DBK-111-1 | *$270* | DBL-111-1 | *$285* |
| Noise Tube Mount with Tube | | | | | | | DBC-140-T | *$325* | DBD-140-T | *$278* | DBE-140-T | *$225* | DBF-140-T | *$230* | DBG-140-T | *$200* | DBH-140-T | *$210* | DBJ-140-T | *$235* | DBK-140-T | *$265* | DBL-140-T | *$300* |
| **Transmission Line Components** | | | | | | | | | | | | | | | | | | | | | | | | |
| Adaptors, Choke to Cover | | | | | | | | | DBD-010 | *$30* | DBE-010 | *$26* | DBF-010 | *$26* | DBG-010 | *$20* | DBH-010 | *$27* | DBJ-010 | *$37* | DBK-010 | *$46* | DBL-010 | *$73* |
| Tapered Transitions | DBWB-018 | *$125* | DBAB-018 | *$100* | DBBC-018 | *$90* | DBCD-018 | *$90* | DBDE-018 | *$85* | DBEF-018 | *$75* | DBFG-018 | *$70* | DBGH-018 | *$45* | DBHJ-018 | *$100* | DBJK-018 | *$115* | DBKL-018 | *$125* | | |
| Rect. to Cylindrical Transitions | | | DBA-030 | *$165* | DBB-030 | *$165* | DBC-030 | *$165* | DBD-030 | *$165* | DBE-030 | *$165* | DBF-030 | *$160* | DBG-030 | *$160* | | | DBJ-030 | *$237* | | | | |
| N to Waveguide Transformers | | | | | | | | | | | | | DBF-057 | *$50* | DBG-057 | *$39* | DBH-057 | *$39* | DBJ-057 | *$50* | DBK-057 | *$55* | DBL-057 | *$78* |
| *Straight Sections | DBW-210 | *$58* | DBA-210 | *$34* | DBB-210 | *$34* | DBC-210 | *$37* | DBD-210 | *$37* | DBE-210 | *$24* | DBF-210 | *$25* | DBG-210 | *$23* | DBH-210 | *$28* | DBJ-210 | *$37* | DBK-210 | *$47* | DBL-210 | *$60* |
| 90° E-Plane Elbows | DBW-224 | *$125* | DBA-224 | *$44* | DBB-224 | *$44* | DBC-224 | *$44* | DBD-224 | *$44* | DBE-224 | *$39* | DBF-224 | *$33* | DBG-224 | *$31* | DBH-224 | *$35* | DBJ-224 | *$49* | DBK-224 | *$68* | DBL-224 | *$98* |
| 90° H-Plane Elbows | DBW-234 | *$125* | DBA-234 | *$44* | DBB-234 | *$44* | DBC-234 | *$44* | DBD-234 | *$44* | DBE-234 | *$39* | DBF-234 | *$33* | DBG-234 | *$31* | DBH-234 | *$35* | DBJ-234 | *$49* | DBK-234 | *$68* | DBL-234 | *$98* |
| Rotating Joints 90-90 | | | | | | | | | DBD-266-1 | *$322* | DBE-266-1 | *$312* | DBF-266-1 | *$286* | DBG-266-1 | *$228* | DBH-266-1 | *$255* | DBJ-266-1 | *$308* | DBK-266-1 | *$358* | DBL-266-1 | *$435* |
| Rotating Joints 90-Col | | | | | | | | | DBD-266-2 | *$342* | DBE-266-2 | *$332* | DBF-266-2 | *$311* | DBG-266-2 | *$285* | DBH-266-2 | *$318* | DBJ-266-2 | *$400* | DBK-266-2 | *$468* | DBL 266-2 | *$615* |
| Rotating Joints Col.-90 | | | | | | | | | DBD-266-3 | *$342* | DBE-266-3 | *$332* | DBF-266-3 | *$311* | DBG-266-3 | *$285* | DBH-266-3 | *$318* | DBJ-266-3 | *$400* | DBK-266-3 | *$468* | DBL-266-3 | *$615* |
| Rotating Joints Col.-Col. | | | | | | | | | DBD-266-4 | *$362* | DBE-266-4 | *$352* | DBF-266-4 | *$336* | DBG-266-4 | *$337* | DBH-266-4 | *$386* | DBJ-266-4 | *$492* | DBK-266-4 | *$578* | DBL-266-4 | *$795* |
| 90° Twisted Sections | DBW-274 | *$117* | DBA-274 | *$44* | DBB-274 | *$44* | DBC-274 | *$44* | DBD-274 | *$44* | DBE-274 | *$39* | DBF-274 | *$33* | DBG-274 | *$31* | DBH-274 | *$35* | DBJ-274 | *$53* | DBK-274 | *$75* | DBL-274 | *$110* |
| Bulkhead Flanges | | | DBA-275 | *$50* | DBB-275 | *$50* | DBC-275 | *$50* | DBD-275 | *$50* | DBE-275 | *$46* | DBF-275 | *$41* | DBG-275 | *$37* | DBH-275 | *$48* | DBJ-275 | *$61* | DBK-275 | *$74* | DBL-275 | *$108* |
| Bulkhead Flanges with Seals | | | DBA-275-1 | *$86* | DBB-275-1 | *$86* | DBC-275-1 | *$86* | DBD-275-1 | *$88* | DBE-275-1 | *$84* | DBF-275-1 | *$89* | DBG-275-1 | *$71* | | | | | | | | |
| Pressurizing Units | | | DBA-276 | *$65* | DBB-276 | *$65* | DBC-276 | *$55* | DBD-276 | *$49* | DBE-276 | *$41* | DBF-276 | *$40* | DBG-276 | *$38* | DBH-276 | *$43* | DBJ-276 | *$52* | DBK-276 | *$63* | DBL-276 | *$75* |
| **Crystal Mounts & Multipliers** | | | | | | | | | | | | | | | | | | | | | | | | |
| Crystal Mounts | | | DBA-310 | *$98* | DBB-310 | *$93* | DBC-310 | *$88* | DBD-310 | *$83* | DBE-310 | *$80* | DBF-310 | *$80* | DBG-310 | *$55* | DBH-310 | *$66* | DBJ-310 | *$75* | DBK-310 | *$88* | DBL-310 | *$128* |
| Crystal Mts., thru Guide, w/Xtal | DBW-312 | *$272* | DBA-312 | *$272* | DBB-312 | *$272* | DBC-312 | *$272* | DBD-312 | *$272* | | | | | | | | | | | | | | |
| Crystal Mounts, Movable Short | DBW-313 | *$307* | DBA-313 | *$130* | DBB-313 | *$125* | DBC-313 | *$120* | DBD-313 | *$110* | DBE-313 | *$110* | DBF-313 | *$110* | DBG-313 | *$79* | DBH-313 | *$125* | DBJ-313 | *$140* | | | | |
| Tunable Crystal Mounts | | | DBA-319 | *$234* | DBB-319 | *$229* | DBC-319 | *$224* | DBD-319 | *$214* | DBE-319 | *$214* | DBF-319 | *$220* | DBG-319 | *$190* | DBH-319 | *$204* | DBJ-319 | *$224* | DBK-319 | *$244* | DBL-319 | *$300* |
| Crystal Multipliers | | | | | DBBW-350 | *$453* | DBCA-350 | *$328* | DBDB-350 | *$328* | DBEC-350 | *$328* | DBFC-350 | *$273* | DBGE-350 | *$268* | DBHF-350 | *$218* | DBJF-350 | *$292* | DBKG-350 | *$309* | DBLJ-350 | *$452* |
| **Power Absorbing Units** | | | | | | | | | | | | | | | | | | | | | | | | |
| Precision Attenuators | DBW-410 | *$537* | DBA-410 | *$358* | DBB-410 | *$358* | DBC-410 | *$358* | DBD-410 | *$358* | DBE-410 | *$358* | DBF-410 | *$270* | DBG-410 | *$250* | DBH-410 | *$275* | DBJ-410 | *$310* | DBK-410 | *$325* | DBL-410 | *$380* |
| Variable Attenuators | DBW-430 | *$275* | DBA-430 | *$150* | DBB-430 | *$130* | DBC-430 | *$120* | DBD-430 | *$115* | DBE-430 | *$110* | DBF-430 | *$220* | DBG-430 | *$200* | DBH-430 | *$225* | DBJ-430 | *$260* | DBK-430 | *$275* | DBL-430 | *$315* |
| Variable Attenuators, Calibrated | | | DBA-430-1 | *$178* | DBB-430-1 | *$158* | DBC-430-1 | *$148* | DBD-430-1 | *$143* | DBE-430-1 | *$138* | | | | | | | | | | | | |
| Fixed Attenuators | | | DBA-440A | *$98* | DBB-440A | *$93* | DBC-440A | *$88* | DBD-440A | *$83* | DBE-440A | *$83* | DBF-440A | *$58* | DBG-440A | *$52* | DBH-440A | *$58* | DBJ-440A | *$66* | DBK-440A | *$75* | DBL-440A | *$85* |
| Low Power Terminations | DBW-450 | *$105* | DBA-450 | *$75* | DBB-450 | *$65* | DBC-450 | *$55* | DBD-450 | *$44* | DBE-450 | *$35* | DBF-450 | *$33* | DBG-450 | *$28* | DBH-450 | *$33* | DBJ-450 | *$40* | DBK-450 | *$49* | DBL-450 | *$65* |
| Movable Low Power Terminations | | | DBA-456A | *$115* | DBB-456A | *$105* | DBC-456A | *$95* | DBD-456A | *$75* | DBE-456A | *$68* | DBF-456A | *$78* | DBG-456A | *$72* | DBH-456A | *$87* | DBJ-456A | *$96* | DBK-456A | *$110* | DBL-456A | *$140* |
| Movable Term. with Extension | | | DBA-456 | *$132* | DBB-456 | *$122* | DBC-456 | *$112* | DBD-456 | *$92* | DBE-456 | *$85* | DBF-456 | *$103* | DBG-456 | *$95* | DBH-456 | *$115* | DBJ-456 | *$133* | DBK-456 | *$157* | DBL-456 | *$213* |
| Movable Term. with Ext. & Vernier | | | DBA-456-1 | *$156* | DBB-456-1 | *$146* | DBC-456-1 | *$136* | DBD-456-1 | *$116* | DBE-456-1 | *$109* | DBF-456-1 | *$127* | DBG-456-1 | *$119* | DBH-456-1 | *$139* | DBJ-456-1 | *$157* | DBK-456-1 | *$181* | DBL-456-1 | *$237* |
| Tunable Low Power Terminations | | | DBA-459 | *$205* | DBB-459 | *$195* | DBC-459 | *$185* | DBD-459 | *$175* | DBE-459 | *$175* | DBF-459 | *$160* | DBG-459 | *$160* | DBH-459 | *$162* | DBJ-459 | *$182* | DBK-459 | *$198* | DBL-459 | *$266* |
| High Power Terminations | | | DBA-460 | *$120* | DBB-460 | *$110* | DBC-460 | *$100* | DBD-460 | *$100* | DBE-460 | *$90* | DBF-460 | *$80* | DBG-460 | *$75* | DBH-460 | *$88* | DBJ-460 | *$125* | DBK-460 | *$129* | DBL-460 | *$150* |
| **Horns** | | | | | | | | | | | | | | | | | | | | | | | | |
| Pickup Horns | | | DBA-510 | *$83* | DBB-510 | *$83* | DBC-510 | *$83* | DBD-510 | *$83* | DBE-510 | *$83* | DBF-510 | *$72* | DBG-510 | *$71* | DBH-510 | *$75* | DBJ-510 | *$80* | DBK-510 | *$90* | DBL-510 | *$110* |
| Standard Gain Horns, 10 DB, 15 DB | DBW-520 | *$180* | DBA-520 | *$92* | DBB-520 | *$92* | DBC-520 | *$92* | DBD-520 | *$92* | DBE-520 | *$92* | DBF-520 | *$84* | DBG-520 | *$82* | DBH-520 | *$88* | DBJ-520 | *$94* | DBK-520 | *$116* | DBL-520 | *$140* |
| Standard Gain Horns, 20 DB | | | DBA-520 | *$106* | DBB-520 | *$106* | DBC-520 | *$106* | DBD-520 | *$106* | DBE-520 | *$106* | DBF-520 | *$95* | DBG-520 | *$94* | DBH-520 | *$99* | DBJ-520 | *$121* | DBK-520 | *$195* | DBL-520 | *$255* |
| Conical Horns | | | DBA-530 | *$165* | DBB-530 | *$165* | DBC-530 | *$165* | DBD-530 | *$165* | DBE-530 | *$165* | DBF-530 | *$182* | DBG-530 | *$178* | | | DBJ-530 | *$204* | | | | |
| **Tees, Junctions and Mixers** | | | | | | | | | | | | | | | | | | | | | | | | |
| E-Plane Tees | DBW-610 | *$150* | DBA-610 | *$65* | DBB-610 | *$60* | DBC-610 | *$58* | DBD-610 | *$58* | DBE-610 | *$51* | DBF-610 | *$41* | DBG-610 | *$38* | DBH-610 | *$46* | DBJ-610 | *$61* | DBK-610 | *$80* | DBL-610 | *$105* |
| Waveguide Switches, 2 Way | | | DBA-616 | *$600* | DBB-616 | *$600* | DBC-616 | *$600* | DBD-616 | *$554* | DBE-616 | *$554* | DBF-616 | *$537* | DBG-616 | *$537* | DBH-616 | *$554* | DBJ-616 | *$651* | DBK-616 | *$680* | DBL-616 | *$835* |
| Waveguide Switches, 4 Way | | | DBA-617 | *$590* | DBB-617 | *$590* | DBC-617 | *$590* | DBD-617 | *$544* | DBE-617 | *$544* | DBF-617 | *$527* | DBG-617 | *$530* | DBH-617 | *$546* | DBJ-617 | *$644* | DBK-617 | *$671* | DBL-617 | *$822* |
| H-Plane Tees | DBW-620 | *$150* | DBA-620 | *$65* | DBB-620 | *$60* | DBC-620 | *$58* | DBD-620 | *$58* | DBE-620 | *$51* | DBF-620 | *$41* | DBG-620 | *$38* | DBH-620 | *$46* | DBJ-620 | *$61* | DBK-620 | *$80* | DBL-620 | *$105* |
| Basic Directional Couplers | | | DBA-630 | *$135* | DBB-630 | *$125* | DBC-630 | *$115* | DBD-630 | *$110* | DBE-630 | *$77* | DBF-630 | *$61* | DBG-630 | *$60* | DBH-630 | *$67* | DBJ-630 | *$82* | DBK-630 | *$110* | DBL-630 | *$160* |
| Directional Couplers, Flg. to Term. | | | DBA-631 | *$145* | DBB-631 | *$135* | DBC-631 | *$125* | DBD-631 | *$120* | DBE-631 | *$86* | DBF-631 | *$68* | DBG-631 | *$67* | DBH-631 | *$75* | DBJ-631 | *$89* | DBK-631 | *$119* | DBL-631 | *$173* |
| Directional Couplers, Coax. to Term. | | | | | | | | | | | | | DBF-632 | *$100* | DBG-632 | *$90* | DBH-632 | *$106* | DBJ-632 | *$119* | DBK-632 | *$146* | DBL-632 | *$216* |
| Directional Couplers, Xtal. to Flg. | | | DBA-633 | *$195* | DBB-633 | *$185* | DBC-633 | *$175* | DBD-633 | *$170* | DBE-633 | *$150* | DBF-633 | *$125* | DBG-633 | *$105* | DBH-633 | *$116* | DBJ-633 | *$140* | DBK-633 | *$170* | DBL-633 | *$248* |
| Directional Couplers, Xtal. to Term. | | | DBA-634 | *$205* | DBB-634 | *$195* | DBC-634 | *$185* | DBD-634 | *$180* | DBE-634 | *$159* | DBF-634 | *$132* | DBG-634 | *$112* | DBH-634 | *$124* | DBJ-634 | *$147* | DBK-634 | *$179* | DBL-634 | *$261* |
| Magic Tees | DBW-650 | *$225* | DBA-650 | *$83* | DBB-650 | *$83* | DBC-650 | *$83* | DBD-650 | *$83* | DBE 650 | *$66* | DBF-650 | *$56* | DBG-650 | *$52* | DBH-650 | *$65* | DBJ-650 | *$80* | DBK-650 | *$100* | DBL-650 | *$150* |
| Matched Magic Tees | | | DBA-655 | *$190* | DBB-655 | *$180* | DBC-655 | *$170* | DBD-655 | *$160* | DBE-655 | *$150* | DBF-655 | *$90* | DBG-655 | *$87* | DBH-655 | *$100* | DBJ-655 | *$115* | DBK-655 | *$140* | DBL-655 | *$185* |
| Balanced Crystal Mixers | | | DBA-665 | *$395* | DBB-665 | *$395* | DBC-665 | *$395* | DBD-665 | *$395* | DBE 665 | *$375* | DBF-665 | *$300* | DBG-665 | *$250* | DBH-665 | *$292* | DBJ-665 | *$303* | DBK-665 | *$326* | DBL-665 | *$365* |

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# QUIPMENT

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| e Designation<br>equency Band in KMC<br>veguide Nomenclature | DBW<br>90-140<br>RG-138/U | | DBA<br>60-90<br>RG-99/U | | DBB<br>50-75<br>RG-98/U | | DBC<br>33-50<br>RG-97/U | | DBD<br>26.5-40<br>RG-96/U | | DBE<br>18-26.5<br>RG-53/U | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* |
| **quency Meters** | | | | | | | | | | | | |
| cision Cavity Wavemeters, | | | | | | | | | | | | |
| eaction Type | DBW-715-1 | *$1,100* | DBA-715-1 | *$541* | DBB-715-1 | *$541* | DBC-715-1 | *$541* | DBD-715-1 | *$541* | DBE-715-1 | *$541* |
| bsorption Type | DBW-715-2 | *$1,220* | DBA-715-2 | *$575* | DBB-715-2 | *$575* | DBC-715-2 | *$575* | DBD-715-2 | *$575* | DBE-715-2 | *$575* |
| ransmission Type | | | DBA-715-3 | *$580* | DBB-715-3 | *$580* | DBC-715-3 | *$580* | DBD-715-3 | *$580* | DBE-715-3 | *$580* |
| erence Cavity, Reaction Type | | | DBA-715-1A | *$525* | DBB-715-1A | *$525* | DBC-715-1A | *$525* | DBD-715-1A | *$525* | DBE-715-1A | *$525* |
| erence Cavity, Absorption | | | DBA-715-2A | *$560* | DBB-715-2A | *$560* | DBC-715 2A | *$560* | DBD-715-2A | *$560* | DBE-715-2A | *$560* |
| erence Cavity, Transmission | | | DBA-715-3A | *$565* | DBB-715-3A | *$565* | DBC-715-3A | *$565* | DBD-715-3A | *$565* | DBE-715-3A | *$565* |
| **pedance Meters** | | | | | | | | | | | | |
| cision Standing Wave | | | | | | | | | | | | |
| Detectors, Complete | DBW-825 | *$895* | DBA-825 | *$610* | DBB 825 | *$610* | DBC-825 | *$610* | DBD-825 | *$564* | DBE-825 | *$564* |
| riage Units Only | DB-820 | *$327* | DB-820 | *$327* | DB-820 | *$327* | DB-820 | *$327* | DB-820 | *$327* | DB-820 | *$327* |
| veguide Sections | DBW-821 | *$350* | DBA-821 | *$206* | DBB-821 | *$206* | DBC-821 | *$206* | DBD-821 | *$179* | DBE-821 | *$179* |
| adband Probes | DBW 822 | *$250* | DBA-822 | *$94* | DBB-822 | *$94* | DBC-822 | *$94* | DBD-822 | *$75* | DBE-822 | *$75* |
| **ase Shifters, Tuners & Shorts** | | | | | | | | | | | | |
| ase Shifters | DBW-915 | *$275* | DBA-915 | *$150* | DBB-915 | *$130* | DBC-915 | *$120* | DBD-915 | *$115* | DBE 915 | *$110* |
| ibrated Phase Shifters | DBW-915-1 | *$355* | DBA-915-1 | *$180* | DBB-915-1 | *$160* | DBC-915-1 | *$150* | DBD-915-1 | *$145* | DBE-915-1 | *$140* |
| iable Stub Tuners | | | DBA-919 | *$148* | DBB-919 | *$148* | DBC-919 | *$148* | DBD-919 | *$148* | DBE-919 | *$148* |
| indrical Phase Shifters | | | DBA-930 | *$165* | DBB-930 | *$165* | DBC-930 | *$165* | DBD-930 | *$165* | DBE-930 | *$165* |
| ed Shorts | | | DBA-960 | *$6* | DBB-960 | *$6* | DBC-960 | *$6* | DBD-960 | *$6* | DBE-960 | *$6* |
| vable Shorts | DBW-969A | *$150* | DBA-969A | *$73* | DBB-969A | *$68* | DBC-969A | *$63* | DBD-969A | *$58* | DBE-969A | *$58* |
| vable Shorts with Vernier | DBW-969A-1 | *$217* | DBA-969A-1 | *$97* | DBB-969A-1 | *$92* | DBC-969A-1 | *$87* | DBD-969A-1 | *$82* | DBE-969A-1 | *$82* |
| vable Shorts with Extension | | | DBA-969 | *$83* | DBB-969 | *$78* | DBC-969 | *$73* | DBD-969 | *$68* | DBE-969 | *$68* |
| vable Shorts with Ext. & Vernier | | | DBA-969-1 | *$107* | DBB-969-1 | *$102* | DBC-969-1 | *$97* | DBD-969-1 | *$92* | DBE-969-1 | *$92* |
| Plane Tuners | DBW-979 | *$380* | DBA-979 | *$175* | DBB-979 | *$170* | DBC-979 | *$165* | DBD-979 | *$160* | DBE-979 | *$145* |
| Plane Tuners with Vernier | DBW-979-1 | *$450* | DBA-979-1 | *$223* | DBB-979-1 | *$218* | DBC-979-1 | *$213* | DBD-979-1 | *$208* | DBE-979-1 | *$193* |
| **cessories** | | | | | | | | | | | | |
| justable Waveguide Supports, Ultramicrowave | DBW-1010 | *$6* | DB-1010 | *$6* | DB-1010 | *$6* | DB-1010 | *$6* | DB-1010 | *$6* | DB-1010 | *$6* |
| justable Waveguide Supports, Microwave | | | | | | | | | DB-1010-1 | *$14* | DB-1010-1 | *$14* |
| aveguide Chassis Mounting Stands | DBW 1012 | *$10* | DBA-1012 | *$10* | DBB-1012 | *$10* | DBC-1012 | *$10* | DBD-1012 | *$10* | DBE-1012 | *$10* |
| aveguide Fastening Screws, Pr. | DBW-1020 | *$1.10* | DBA-1020 | *$1.10* | DBB-1020 | *$1.10* | DBC-1020 | *$1.10* | DBD-1020 | *$1.10* | DBE-1020 | *$1.10* |
| aveguide Window Seals | | | DBA-1100 | *$38* | DBB-1100 | *$38* | DBC-1100 | *$38* | DBD-1100 | *$38* | DBE-1100 | *$38* |

| e Designation<br>equency Band in KMC<br>veguide Nomenclature | DBF<br>12.4-18<br>RG-91/U | | DBG<br>8.2-12.4<br>RG-52/U | | DBH<br>7.05-10.0<br>RG-51/U | | DBJ<br>5.85-8.2<br>RG-50/U | | DBK<br>3.95-5.85<br>RG-49/U | | DBL<br>2.6-3.95<br>RG-48/U | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* | Cat. No. | *Price* |
| **quency Meters** | | | | | | | | | | | | |
| cision Cavity Wavemeters, | | | | | | | | | | | | |
| eaction Type | DBF-715-1 | *$503* | DBG-715-1 | *$487* | DBH-715-1 | *$525* | DBJ-715-1 | *$564* | DBK-715-1 | *$613* | DBL-715-1 | *$839* |
| bsorption Type | DBF-715-2 | *$536* | DBG-715-2 | *$520* | DBH-715-2 | *$558* | DBJ-715-2 | *$597* | DBK-715-2 | *$646* | DBL-715-2 | *$883* |
| ransmission Type | DBF-715-3 | *$542* | DBG-715-3 | *$525* | DBH-715-3 | *$564* | DBJ-715-3 | *$608* | DBK-715-3 | *$657* | DBL-715-3 | *$894* |
| erence Cavity, Reaction Type | DBF-715-1A | *$487* | DBG-715-1A | *$470* | DBH-715-1A | *$509* | DBJ-715-1A | *$547* | DBK-715-1A | *$597* | DBL-715-1A | *$800* |
| erence Cavity, Absorption | DBF-715-2A | *$520* | DBG-715-2A | *$503* | DBH-715-2A | *$542* | DBJ-715-2A | *$580* | DBK-715-2A | *$630* | DBL-715-2A | *$844* |
| erence Cavity, Transmission | DBF-715-3A | *$525* | DBG-715-3A | *$509* | DBH-715-3A | *$547* | DBJ-715-3A | *$591* | DBK-715-3A | *$641* | DBL-715-3A | *$855* |
| **pedance Meters** | | | | | | | | | | | | |
| cision Standing Wave | | | | | | | | | | | | |
| Detectors, Complete | DBF-825 | *$525* | DBG-825 | *$465* | DBH-825 | *$470* | DBJ-825 | *$479* | | | | |
| riage Units Only | DB-820 | *$327* | DB-820-1 | *$267* | DB-820-1 | *$267* | DB-820-1 | *$267* | | | | |
| veguide Sections | DBF-821 | *$152* | DBG-821 | *$152* | DBH-821 | *$157* | DBJ-821 | *$166* | | | | |
| adband Probes | DBF-822 | *$61* | DBG-822 | *$61* | DBH-822 | *$61* | DBJ-822 | *$61* | | | | |
| **ase Shifters, Tuners & Shorts** | | | | | | | | | | | | |
| ase Shifters | DBF-915 | *$220* | DBG-915 | *$200* | DBH-915 | *$225* | DBJ-915 | *$260* | DBK-915 | *$275* | DBL-915 | *$315* |
| ibrated Phase Shifters | DBF-915-1 | *$270* | DBG-915-1 | *$250* | DBH-915-1 | *$275* | DBJ-915-1 | *$310* | DBK-915-1 | *$325* | DBL-915-1 | *$380* |
| iable Stub Tuners | DBF-919 | *$152* | DBG-919 | *$147* | DBH-919 | *$152* | DBJ-919 | *$165* | DBK-919 | *$180* | DBL-919 | *$230* |
| indrical Phase Shifters | DBF-930 | *$160* | DBG-930 | *$160* | | | DBJ-930 | *$204* | | | | |
| ed Shorts | DBF-960 | *$8* | DBG-960 | *$8* | DBH-960 | *$9* | DBJ-960 | *$10* | DBK-960 | *$11* | DBL-960 | *$13* |
| vable Shorts | DBF-969A | *$63* | DBG-969A | *$60* | DBH-969A | *$76* | DBJ-969A | *$82* | DBK-969A | *$92* | DBL-969A | *$120* |
| vable Shorts with Vernier | DBF-969A-1 | *$112* | DBG-969A-1 | *$110* | DBH-969A-1 | *$126* | DBJ-969A-1 | *$150* | DBK-969A-1 | *$160* | DBL-969A-1 | *$188* |
| vable Shorts with Extension | DBF-969 | *$87* | DBG-969 | *$82* | DBH-969 | *$104* | DBJ-969 | *$118* | DBK-969 | *$135* | DBL-969 | *$188* |
| vable Shorts with Ext. & Vernier | DBF-969-1 | *$137* | DBG-969-1 | *$132* | DBH-969-1 | *$154* | DBJ-969-1 | *$186* | DBK-969-1 | *$203* | DBL-969-1 | *$256* |
| Plane Tuners | DBF-979 | *$165* | DBG-979 | *$158* | DBH-979 | *$193* | DBJ-979 | *$219* | DBK-979 | *$252* | DBL-979 | *$325* |
| Plane Tuners with Vernier | DBF-979-1 | *$215* | DBG-979-1 | *$208* | DBH-979-1 | *$250* | DBJ-979-1 | *$300* | DBK-979-1 | *$335* | DBL-979-1 | *$400* |
| **cessories** | | | | | | | | | | | | |
| justable Waveguide Supports, Ultramicrowave | | | | | | | | | | | | |
| justable Waveguide Supports, Microwave | DB-1010-1 | *$14* | DB-1010-1 | *$14* | DB-1010-1 | *$14* | DB-1010-1 | *$14* | DB-1010-2 | *$14* | DB-1010-2 | *$14* |
| aveguide Chassis Mounting Stands | DBF-1012 | *$10* | DBG-1012 | *$11* | DBH-1012 | *$12* | DBJ-1012 | *$14* | DBK-1012 | *$15* | DBL-1012 | *$17* |
| aveguide Fastening Screws, Pr. | DBF-1020 | *$1.10* | DBG-1020 | *$1.10* | DBH-1020 | *$1.20* | DBJ-1020 | *$1.30* | DBK-1020 | *$1.30* | DBL-1020 | *$1.65* |
| aveguide Window Seals | DBF-1100 | *$33* | DBG-1100 | *$33* | DBH-1100 | *$33* | | | | | | |

| **ectronic Equipment** | | |
|---|---|---|
| F Transformer Box | DB-1502 | *$125* |
| mote Control Box | DB-2016 | *$250* |
| ise Diode Power Supply | DB-2140 | *$200* |

Prices subject to change without notice.

***Deliveries: 2 weeks to 30 days on most items. New 1961 catalog on request.***

# BONARDI

**DE MORNAY-BONARDI**
*780 South Arroyo Parkway, Pasadena, California*

Circle Reader Service Card 26

# Industry News

*(Continued from page 34)*

### STUDY REVEALS SYSTEM OF DETERMINING WEATHER CONDITIONS

Accurate determination of weather variables in areas up to 25 miles away is now possible without venturing into the area under study, according to scientists at Armour Research Foundation.

A study conducted by ARF for the U. S. Army Signal Corps indicates that it is possible to determine the following weather variables at a remote point: temperature, relative humidity, air pressure and wind direction and speed. The proposed system also is refined in the sense that it could determine these weather factors at heights up to 5,000 feet and, using an accompanying computer, provide a meteorological profile.

The information would be valuable to a field army or research team and could be used for many purposes: combat intelligence, missile work, battlefield surveillance, and determining atmospheric conditions in defense against chemical or biological attack.

Two methods could be used in the ARF surveillance system for measuring temperature by passive means: a) a microwave radiometer which measures the emission from $0_2$ in the 60 kMc region of the microwave spectrum and b) a radiometer to measure the emission from $CO_2$ in the 4.3 micron region of the infrared spectrum. The one system is primarily a radar instrument, the other an optical instrument.

*—mwj—*

### MOTOROLA RECEIVES HIGH POWER PULSE TRANSPONDER AWARD

Motorola Inc., Scottsdale, Ariz., has received a $350,000 contract to develop and produce high power C-band pulse transponders for the Air Force Missile Test Center at Patrick Air Force Base, Florida.

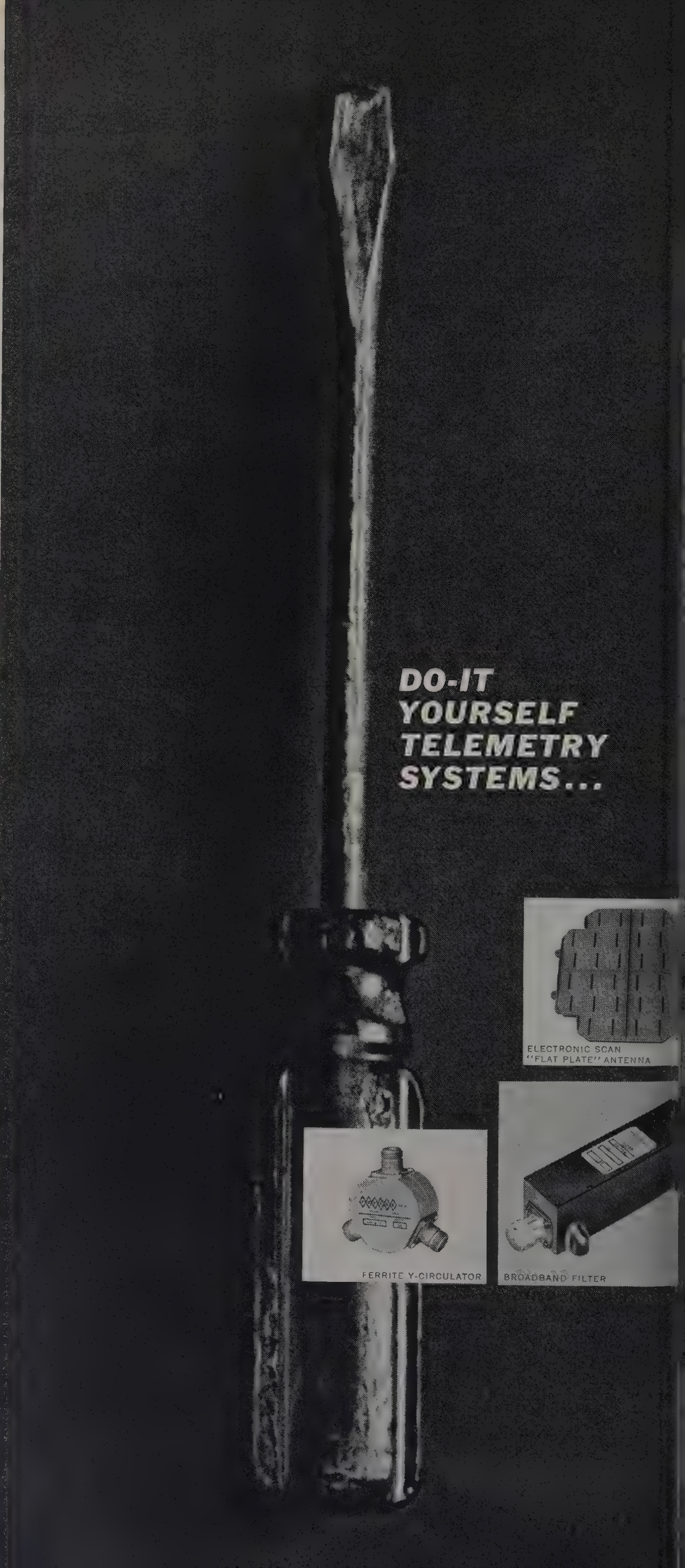
The award calls for an initial quantity of four prototype transponders to be developed by the Western Center of Motorola's Military Electronics Division.

The new transponder will have applications for scientific missile and satellite tracking, according to Liscum Diven, manager of Motorola's Transponder Laboratory. The range of the transponder will exceed that of any presently available pulse type unit, he stated. For these applications, the transponder will greatly extend the range of precision C-band tracking radars such as AN/FPS-16, AN/FPQ-6, and AN/TPQ-18.

It will utilize a new 40 kw magnetron and a Motorola-developed high power ferrite circulator. Deliveries of the transponders will begin this fall, the company indicated.

*—mwj—*

*(Continued on page 39)*

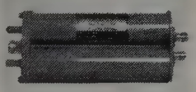


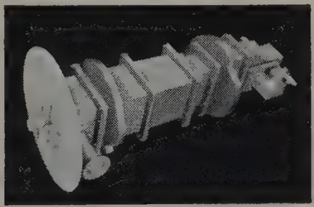
**with**
**mponents**
**Rantec**

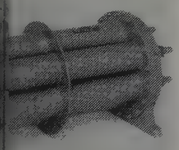
*he past years, Rantec has concentrated a major part*
*research and development efforts in the design and*
*pment of components and subsystems for telemetry.*
*c is now able to offer the design engineer near complete*
*s in today's 225-300 Mc and tomorrow's 1700-2300*
*nds. Here are components of amazing adaptability*
*e design of Rantec-reliable telemetry systems.*

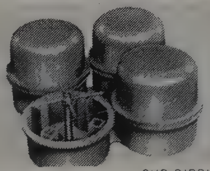
**THE 225-300 MC SYSTEM** *Antennas and arrays, for manual*
*ing and simultaneous lobing... Helical arrays... dipole diversity*
*tion arrays or feeds for large reflectors... these antennas have*
*used successfully in DISCOVERER, EXPLORER, PIONEER*
*CHO projects... Antenna pedestals and servo mounts*
*etry multiplexers... units which combine two to six*
*nitters into one antenna... long term, hermetically sealed*
*ter space environment. Units are used in TITAN, POLARIS,*
*CURY, DISCOVERER, SUBROC, X-15 and other projects*

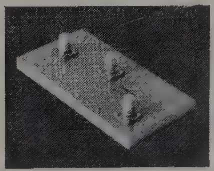
**THE 1700-2300 MC SYSTEM** *Simultaneous lobing and*
*onic conical scanning antennas... Horn arrays and slot arrays*
*for 6′ to 85′ diameter reflectors... used around the world*
*s... coaxial and stripline... designed for rugged ground and space*
*onments... Multiplexers... two to ten channel applications*
*id assemblies... to be used with simultaneous lobing systems*
*rmit tracking by providing sum and difference channel outputs*
*channel rotary joints... Control and display panels...*
*culators... broad-band, compact... for use with parametric*
*ifiers ... Coaxial isolators... ferrite switches*


2 CHANNEL MULTIPLEXER

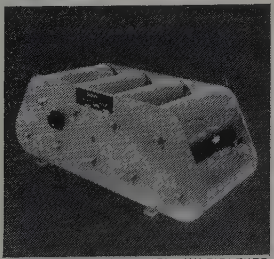

TRANSMITTING-TRACKING FEED FOR 85′ DISH

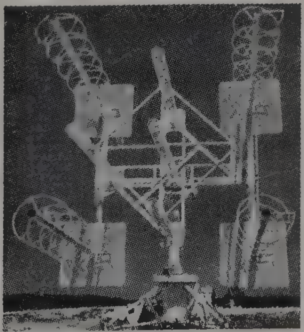

CHANNEL MULTIPLEXER

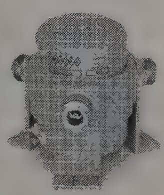

CUP-DIPOLE

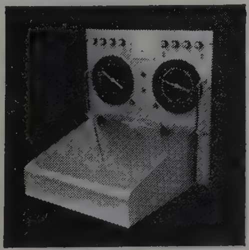

STRIPLINE DIPLEXING FILTER

Y JOINT


LOW-LOSS, 3-CHANNEL MULTIPLEXER


MULTI-FREQ. HELIX TRACKING ARRAY


FERRITE SWITCH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*plete specifications for each component and subsystem are available.*
*ec engineers will be happy to work with your telemetry team in the application*
*ese components to the total system.*

rantec

Corporation, Calabasas, California

## Industry News

*(Continued from page 38)*

### BOEING TO MARKET FIBER GLASS ANTENNA REFLECTORS

Close-tolerance fiber glass antenna reflectors which could be used to measure radiation from other planets soon will be marketed to government and industry agencies by The Boeing Co., Seattle, Wash.

Capable of holding their shape under heavy wind forces and extreme temperatures and giving stronger focus to radio waves, antennas equipped with the new reflectors could also be used to track satellites or to transmit and receive long range communications.

Ray Glaser, Boeing antenna department manager, in announcing the new device, said that the Boeing fiber glass reflectors can hold a surface tolerance of .005 inch. Dents in an antenna reflector, he explained, like pock marks in a camera lens, limit the fineness of focus.

A dish-like antenna reflector catches radio waves and concentrates them on a receiver probe much like a magnifying glass focusing sunlight on one spot.

*— m w j —*

### AMPLIFICATION OF SOUND WAVES BY "STIMULATED EMISSION" DEMONSTRATED

Direct amplification of sound waves using microwave radio energy as a power source has been demonstrated by Dr. Edmund B. Tucker of the General Electric Research Laboratory. Amplification of the sound waves — called phonons — is accomplished by "stimulated emission" of energy by atoms as they change from a higher to a lower energy level. This is the same mechanism used in the Maser (Microwave Amplification by Stimulated Emission of Radiation) to amplify electromagnetic radiation and the new phenomenon has been termed the phonon Maser effect.

*(Continued on page 41)*

◆ **Circle Reader Service Card 28**

# 124 completely hermetically sealed Microwave Mixer and Video Diodes

ALL ARE DIRECTLY SUBSTITUTABLE
FOR CONVENTIONAL DIODES
TO ASSURE UNPRECEDENTED
SYSTEMS RELIABILITY.

Microwave Associates has answered your need for truly hermetically-sealed diodes. For the first time, both fixed-base and reversible polarity types have CERAMIC-TO-METAL SOLDER SEALS plus SOLDER END SEALS.

Whatever the requirement – from 1 Mc to 18 kMc, a new diode is available to replace the present diode — extra high burnout types for high signal level circuits and behind radar duplexers—new low-noise types for doppler receivers.

The MA-458F, for example, replacing the 1N23E, has a calculated overall noise figure of 7.0 db — the lowest noise figure available for high reliability applications.

These diodes (and coaxial case and subminiature glass packaged diodes) assure military and commercial applications the reliability essential to uninterrupted service for exceptional time spans. They perform to 150°C and meet the applicable environmental requirements of MIL-S-19500.

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## SILICON MIXER DIODES

### 1 Mc — 4,000 Mc

### CARTRIDGE CASE

**Improved Types**
For low noise superheterodyne mixer performance
• Replace 1N21 series

| Fixed Base Types | | Matched Pair | | Reversible Polarity Types | Calc. Overall Rec'r Noise Figure $N_{if}$ = 1.5db (db) | Burnout Rating (ergs) |
|---|---|---|---|---|---|---|
| Forward Polarity | Reversed Polarity | Forward Pair | Forward & Reversed | | | |
| MA-449B | MA-449BR | MA-449BM | MA-449BMR | MA-459B | 10.3 | 5.0 |
| MA-449C | MA-449CR | MA-449CM | MA-449CMR | MA-459C | 8.3 | 5.0 |
| MA-449D | MA-449DR | MA-449DM | MA-449DMR | MA-459D | 7.3 | 5.0 |
| MA-449E | MA-449ER | MA-449EM | MA-449EMR | 1N21WE | 7.0 | 5.0 |
| MA-449F | MA-449FR | MA-449FM | MA-449FMR | MA-459F | 6.0 | 5.0 |

**Higher Burnout Types**
For use in pulse radars or other receivers exposed to high RF radiation fields.
• Interchangeable with 1N21 series

| | | | | | | |
|---|---|---|---|---|---|---|
| MA-4127 | MA-4127R | MA-4127M | MA-4127MR | MA-4132 | 8.3 | 10 |

**Lower Noise Types**
For best signal-to-noise performance in low frequency IF doppler systems.

| | | | | | | |
|---|---|---|---|---|---|---|
| MA-4126 | MA-4126R | MA-4126M | MA-4126MR | MA-4131 | — | 2.0 |
| MA-4126A | MA-4126AR | MA-4126AM | MA-4126AMR | MA-4131A | — | 2.0 |

### 4,000 Mc — 10,000 Mc

**Improved Types**
For low noise superheterodyne mixer performance.
• Replace 1N23 series

| | | | | | | |
|---|---|---|---|---|---|---|
| MA-451B | MA-451BR | MA-451BM | MA-451BMR | MA-458B | 11.4 | 2.0 |
| MA-451C | MA-451CR | MA-451CM | MA-451CMR | MA-458C | 9.8 | 2.0 |
| MA-451D | MA-451DR | MA-451DM | MA-451DMR | MA-458D | 8.2 | 2.0 |
| MA-451E | MA-451ER | MA-451EM | MA-451EMR | IN23WE | 7.5 | 2.0 |
| MA-451F | MA-451FR | MA-451FM | MA-451FMR | MA-458F | 7.0 | 2.0 |

**Higher Burnout Types**
For use in pulse radars or other receivers exposed to high RF radiation fields.
• Interchangeable with 1N23 series

| | | | | | | |
|---|---|---|---|---|---|---|
| MA-4133 | MA-4133R | MA-4133M | MA-4133MR | MA-4134 | 9.8 | 5.0 |

**Lower Noise Types**
For best signal-to-noise performance in low frequency IF doppler systems.

| | | | | | | |
|---|---|---|---|---|---|---|
| MA-4125 | MA-4125R | MA-4125M | MA 4125MR | MA-4130 | — | 2.0 |
| MA-4125A | MA-4125AR | MA-4125AM | MA-4125AMR | MA-4130A | — | 2.0 |

### 10,000 Mc — 18,000 Mc

### COAXIAL CASE

**Improved Types**
For low noise superheterodyne mixer performance.
• Replace 1N78 series

| | | | | | | |
|---|---|---|---|---|---|---|
| MA-433 | MA-443R | MA-443M | MA-443MR | — | — | 0.6 |
| MA-443A | MA-443AR | MA-443AM | MA-443AMR | — | 9.8 | 0.6 |
| MA-443B | MA-443BR | MA-443BM | MA-443BMR | — | 8.8 | 0.6 |
| MA-445 | MA-445R | MA-445M | MA-445MR | — | — | 1.0 |
| MA-445A | MA-445AR | MA-445AM | MA-445AMR | — | 9.8 | 1.0 |
| MA-445B | MA-445BR | MA-445BM | MA-445BMR | — | 8.8 | 1.0 |

**Lower Noise Types**
For best signal-to-noise performance in low frequency IF doppler systems.

| | | | | | | |
|---|---|---|---|---|---|---|
| MA-4124 | MA-4124R | MA-4124M | MA-4124MR | — | — | 0.6 |
| MA-4124A | MA-4124AR | MA-4124AM | MA-4124AMR | — | — | 0.6 |

## SILICON VIDEO DIODES

### 1 Mc — 10,000 Mc

**Improved Types** For high tangential signal-to-noise sensitivity in simplified beacon receivers, test equipment and other uses.
• Replace MA-408 series **CARTRIDGE CASE**

| Fixed Base Types | | Reversible Polarity | Burnout (ergs) |
|---|---|---|---|
| Forward Polarity | Reversed Polarity | | |
| MA-452 | MA-452R | MA-461 | 1.0 |
| MA-452A | MA-452AR | MA-461A | 1.0 |
| MA-452B | MA-452BR | MA-461B | 1.0 |

**Higher Burnout Wide Dynamic Range Types**
For use in video receivers exposed to high RF radiation fields.
• Interchangeable with MA-408 series

| | | | |
|---|---|---|---|
| MA 4128 | MA 4128R | MA 4129 | 5.0 |

Circle Reader Service Card 29

(Continued from page 39)

According to Dr. Guy Suits, General ectric vice president and director of earch, this is the first time that stimu- ed emission has been successfully used amplify energy other than electromag- tic energy. Dr. Suits noted that, al- ough no immediate commercial applica- n of the phenomenon is in sight, it ovides a significant extension of the inciple of stimulated emission, and rep- sents an advance in understanding of e physics of the solid state.

The technique may also provide a valu- le research tool permitting experimental dy of the role of phonons in many ysical phenomena. For example, it may ke possible an acoustic oscillator for nerating sound waves of higher fre- ency than are now attainable.

In both the Maser and the new phonon ser effect, individual atoms are raised a high energy state by irradiating — "pumping" — them with high fre- ency electromagnetic energy. Then, en signal energy of a lower frequency introduced, stimulated emission of the gnal frequency occurs. Under the proper nditions, the stimulated emission may strong enough to produce amplification the signal. In the Maser, the pump, gnal and output are all electromagnetic ergy, whereas in the phonon Maser ef- t only the pump is electromagnetic ergy — the signal and output are both echanical, or sound, energy.

*— m w j —*

## NAVY CONTRACTS AWARD $16.4 MILLION TO SPERRY

Contracts totaling $16.4 million for ipboard radar and underwater detection stems have been awarded to two Sperry and Corporation divisions, it was an- unced by the U. S. Navy.

Sperry Gyroscope Co., Great Neck, . Y., received three contracts totaling 3.7 million, and Sperry Piedmont Co., harlottesville, Va., received another for .7 million.

Seven-and-a-half million dollars will be nployed by Sperry for modification and nprovement of Talos missile guidance dars. Approximately $4.8 million will ovide for continued production of a new ssive underwater detection system for bmarines and $1.4 million is slated for dar engineering and technical services.

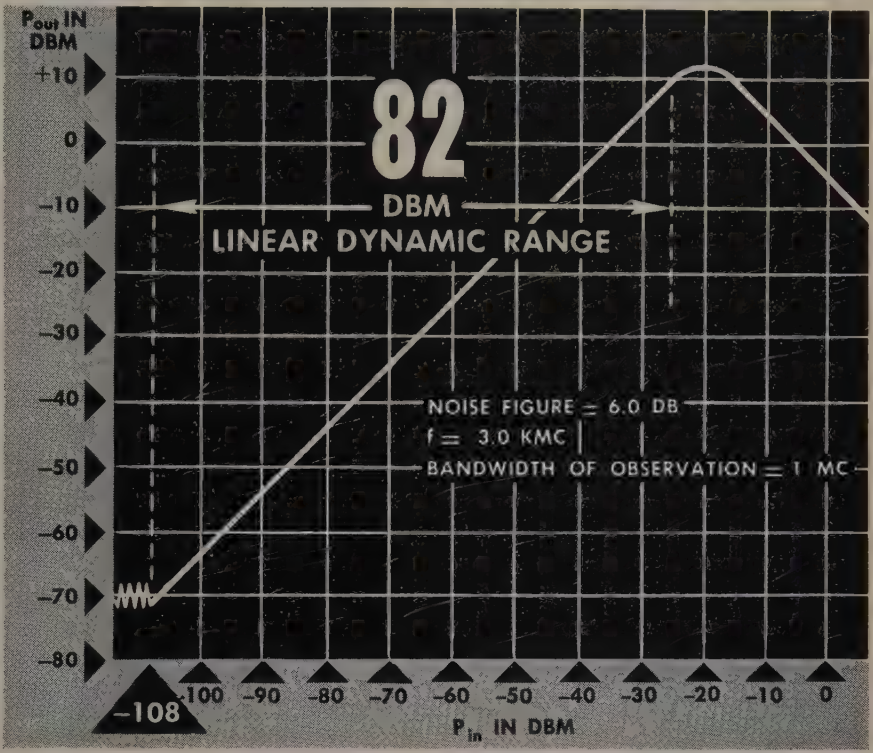
Sperry Piedmont's $2.7 million will rther increase the reliability and per- rmance of original Terrier missile idance radars.

Talos and Terrier missiles are a major rface-to-air armament for new classes of avy cruisers and aircraft carriers. They re capable of delivering a nuclear war- ead against all types of aircraft.

*— m w j —*

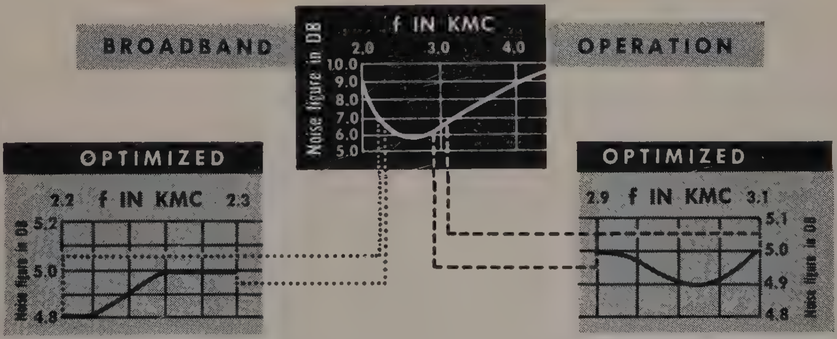
(Continued on page 42)

Low-noise TWTs . . .
wide dynamic range



Huggins low-noise traveling wave tubes provide 7 DBM minimum saturation P_out over major portions of octave bandwidths—coincident with low-noise performance. An example is the HA-70 characteristics shown above. The low noise figure plus high P_out results in the maximum degree of linear operation consistent with the present state of the TWT manufacturing art.

S-band low-noise tubes perform at extremely low noise levels, shown typically below, in solenoids requiring 125 watts maximum power and weighing 25 pounds.



**Huggins low-noise tubes carry a 1500 hour warranty.**

Contact Huggins for further TWT information, including modification of standard tubes to your system specifications.

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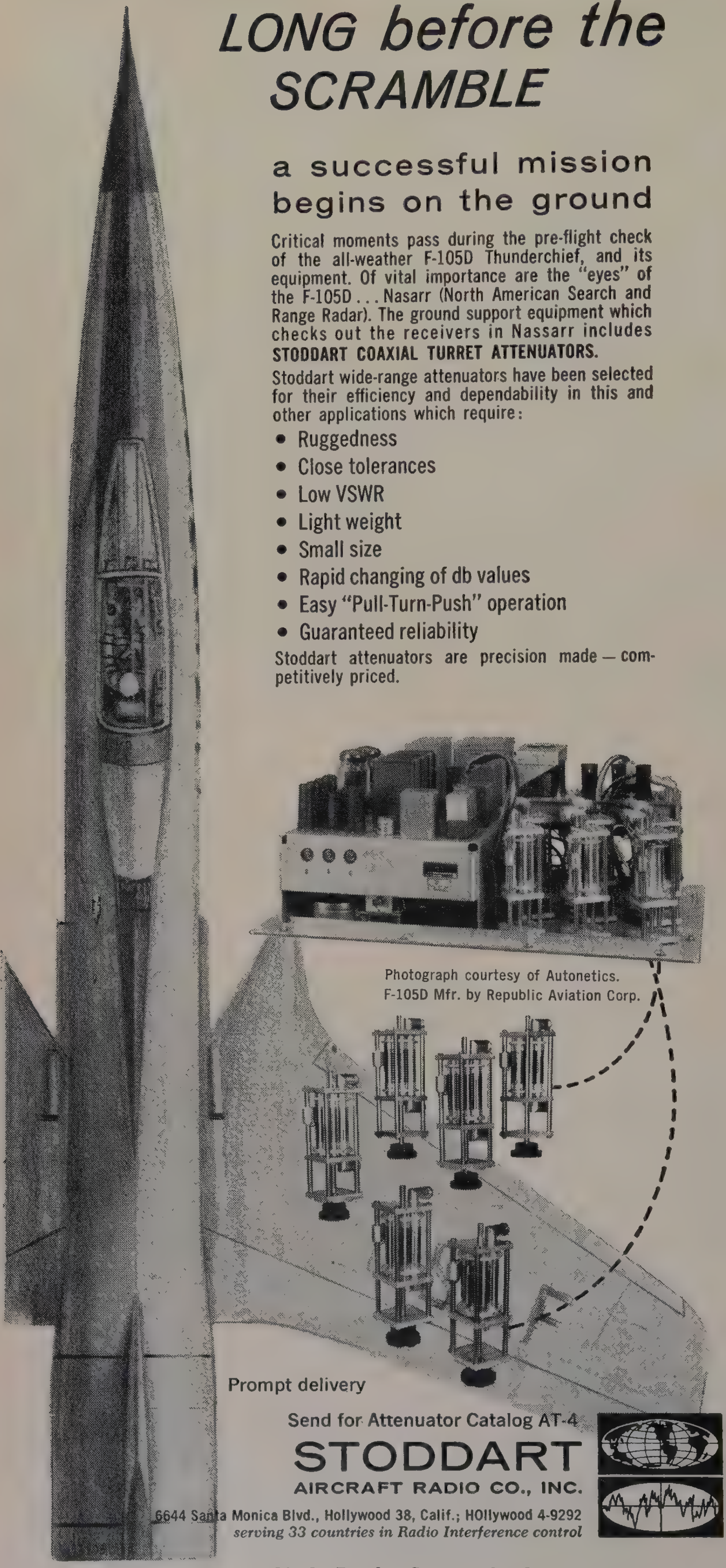

CRITICAL MOMENTS!
LONG before the
SCRAMBLE

a successful mission
begins on the ground

Critical moments pass during the pre-flight check of the all-weather F-105D Thunderchief, and its equipment. Of vital importance are the "eyes" of the F-105D . . . Nasarr (North American Search and Range Radar). The ground support equipment which checks out the receivers in Nassarr includes **STODDART COAXIAL TURRET ATTENUATORS.**

Stoddart wide-range attenuators have been selected for their efficiency and dependability in this and other applications which require:

- Ruggedness
- Close tolerances
- Low VSWR
- Light weight
- Small size
- Rapid changing of db values
- Easy "Pull-Turn-Push" operation
- Guaranteed reliability

Stoddart attenuators are precision made — competitively priced.

Photograph courtesy of Autonetics.
F-105D Mfr. by Republic Aviation Corp.

Prompt delivery

Send for Attenuator Catalog AT-4

**STODDART**
**AIRCRAFT RADIO CO., INC.**
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*serving 33 countries in Radio Interference control*

**Circle Reader Service Card 31**

## Industry News

*(Continued from page 41)*

### LIPPITT JOINS ANTENNA SYSTEMS

Charles W. Creaser, Jr., president, Antenna Systems Inc., Hingham, Mass., has announced that Kendrick H. Lippitt has joined the company as vice president in charge of the new Pacific Division.

Mr. Lippitt has been associated with the antenna industry for many years. He comes to ASI from Rohr Aircraft Corp., where he was manager of the Antenna Systems Division.

He received a BS Degree from the Massachusetts Institute of Technology, has taken graduate courses at Cornell University, attended the Naval radar schools, and is a member of the IRE.

— *mwj* —

### SURVEY BREAKS DOWN ENGINEERING SCIENTIFIC MANPOWER IN ELECTRONICS

An estimated 76 per cent of all engineers and scientists employed by the U.S. electronics industry are supported by government funds, according to a survey recently conducted by the Electronic Industries Association with the cooperation of the Department of Defense. The remaining 24 per cent is engaged in commercially supported activities.

The report discloses that there are an estimated 155,000 engineers and scientists performing electronics work in all areas. Eighty-three per cent or 128,000 are employed by industry, while 8 per cent are working for the Federal Government and 5 per cent are doing research work for universities and non-profit organizations. The remainder comprises independent consultants, engineers and scientists between jobs, and those not identifiable by area of electronic activity.

"The large number of engineers and scientists employed by the electronics industry constitutes one of our country's most vital national resources," EIA President L. Berkley Davis said in announcing results of the survey.

"It is important that officials of the Defense Department, military contractors, and other industry leaders are sufficiently informed as to the distribution of this technical manpower among government and commercially supported activities in order to avoid possible adverse effects of major shifts in defense programming. This survey was conducted for the purpose of providing this information to industry and the Department of Defense."

— *mwj* —

*(Continued on page 50)*

# ULTRASTABLE MICROWAVE SIGNALS...

## their generation and the measuring and analyzing of their perturbations

*by* PETER P. JORRENS
*Engineer, Instrument Division*
*LABORATORY FOR ELECTRONICS, INC.*

At frequencies over 2 Gc/s, the generation of extremely stable microwave signals is a substantial problem. And even more vexing is the problem of determining just how stable a signal is, once a very stable signal is believed to have been achieved. Such problems have become important since microwave signal sources are now needed in many diverse fields wherein stability to a few cycles per second is necessary or desirable.

For all critical applications, two kinds of instability are of primary concern: residual frequency modulation, periodic or non-periodic, as well as its cause, which we call short-term instability; and drift, which long-term instability.

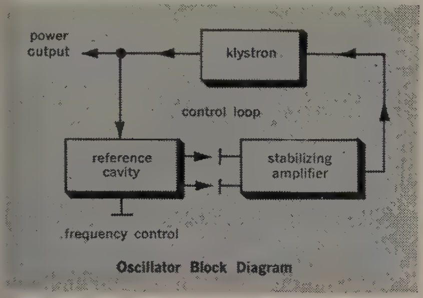


Figure 1

The best commercially available signal generators have these specifications: residual fm of approximately five parts in $10^8$ or better; drift, one part in $10^6$ per hour under ordinary environmental conditions. As shown in Figure 1, a reflex klystron is employed as the generator, part of whose output is fed to a dual-mode invar reference cavity acting as a frequency discriminator. After rectification, any error signal is greatly amplified and employed to keep the klystron closely locked to the mean frequency of the dual-mode cavity.

However, this is not all. Rugged mechanical design, dc on all critical electron tube heaters, broadband crystal mounts with high sensitivity, and electronically regulated power supplies as well as years of production experiences are required to permanently subdue some nasty problems and to meet the specifications mentioned.

The only commercially available instrument capable of checking ultrastable oscillators to such specifications is arranged as shown in Figure 2, and employs a unique quantizing circuit to detect f-m modulation and frequency drift. Up to the point of detection, the circuit is basically that of a double superheterodyne receiver of extraordinary stability and refinement. There is one difference however: because of extreme limiting in the 2nd i-f amplifier, a sinusoidal input signal is converted to very steep-edged square waves. These are differentiated, and the positive-going spikes are used to trigger a multivibrator which, by means of a delay line, generates one constant-energy pulse for each cycle of input to the 2nd i-f amplifier. Each pulse has a constant amplitude E and constant width t.

The average output voltage is $E_o = E\,t\,f$ where f, the 2nd i-f frequency, is the only variable. By using a d-c, zero-center voltmeter, with graduations in kc/s, plus or minus frequency drift can be measured around the initial frequency of the oscillator under test.

If frequency modulation exists, there is an a-c component superposed on the average d-c level whose magnitude is $dE_o = E\,t\,df$. To recover this component for display, the quantized pulse train is filtered to remove the 120 kc/s carrier and frequencies over 20 kc/s, amplified, rectified, and applied to a meter calibrated to read peak frequency deviation.

This particular instrument, with a bandpass from 15 cp/s to 20 kc/s, has drift scales of ± 5 and ± 50 kc/s, eight peak deviation ranges from 10 to 30,000 cps. Minimum measurable f-m deviation varies from 0.3 cps at L-band to 2 cps at Ku band.

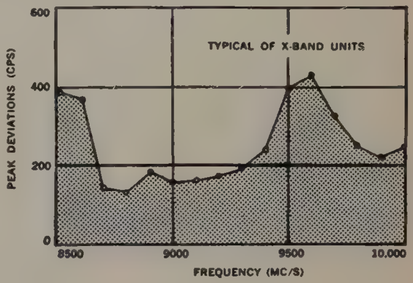


Figure 3

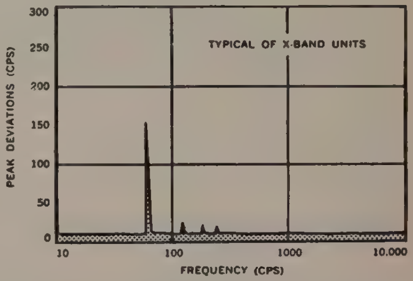


Figure 4

LFE makes both of these instruments: the 814 Series of Ultrastable Oscillators and the Model 5024 Stability Tester. Figures 3 and 4 illustrate typical X-band peak deviation versus output and disturbance frequencies respectively, and figure 5 shows both a Model 814 oscillator and a Model 5024 stability tester. The small instrument, also shown and available, is a Model 240 tunable filter for spectrum analysis of disturbance frequencies.

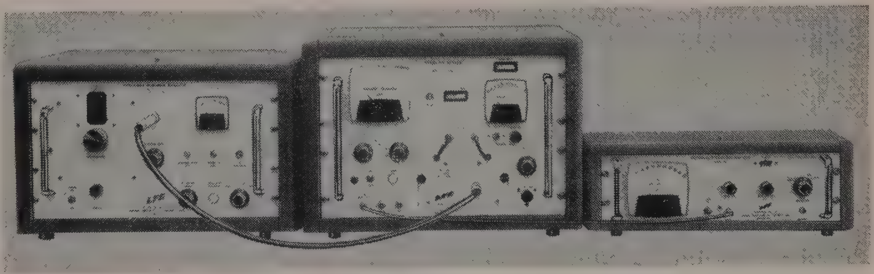
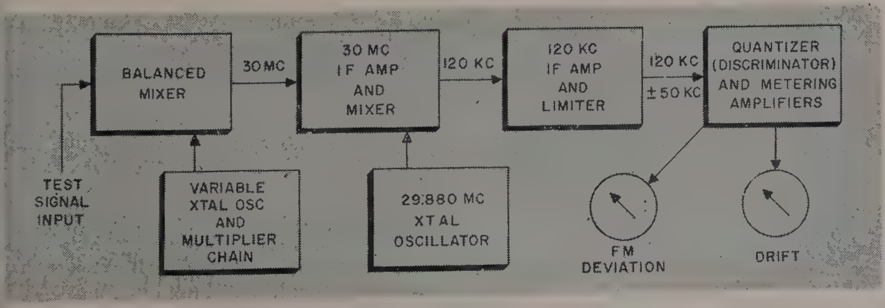


Figure 5

Figure 2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30 MC IF AMP AND MIXER
120 KC
120 KC IF AMP AND LIMITER
120 KC
±50 KC
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An interested reader can obtain much more detailed information by requesting Bulletins 814 and 5024. For these bulletins, or the answers to particular questions, write Mr. Perry Pollins at the address below.

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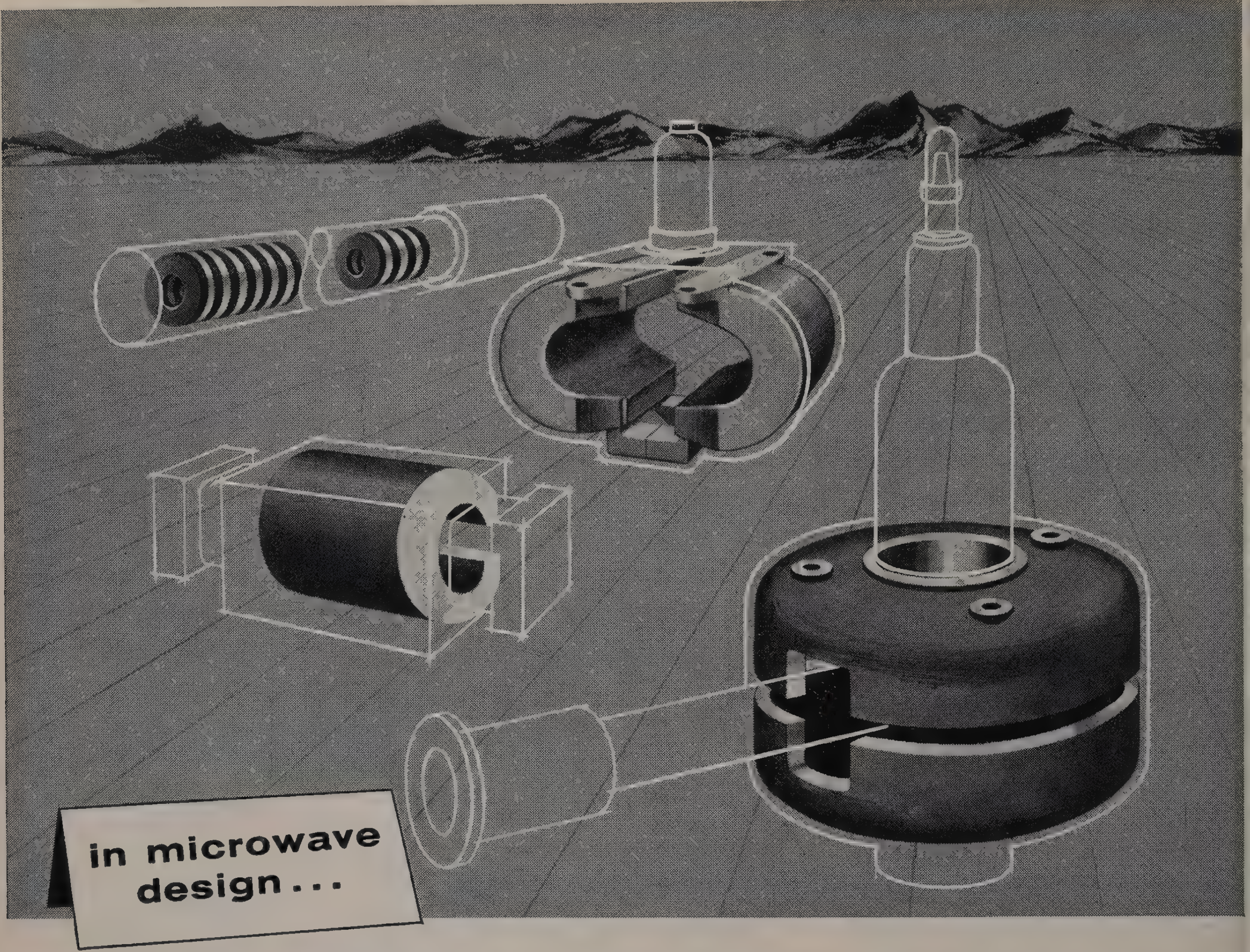

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*" . . . WHY SHOULDN'T A CORPORATE 'INDIVIDUAL' WHO MAKES AN IMPORTANT CONTRIBUTION TO THE MICROWAVE INDUSTRY GET SOME REWARD?"*

# Recovering Engineering Costs - - A Growing Challenge To the Small Businessman

**By IRVING M. GROSS**

One of the major problems facing the small business man engaged in microwave work is the recovery of engineering and development costs for component improvement. The magnitude of this problem is already having far-reaching effects on the nation's technological progress and is creating an undue burden on many small companies.

The enigma of how to recoup funds spent voluntarily for the improvement of the state of the art is particularly serious in the microwave industry, since the great majority of companies in this field are relatively small, self-contained component manufacturers, each of whom contributes a specialized part or parts to the final whole. This seriousness is further increased by the unusual "customer" situation in our industry — virtually everyone's final customer is the United States Government. There is better chance of recovering such engineering costs when working on proprietary commercial products.

It is important to the future of the microwave industry to understand the effects of this problem on our business, how it came about and what steps we, as an industry, can advocate to achieve a proper and prompt solution.

For many years the Government has required that two limitations be included in its contracts. First, there are to be no patent rights on items developed for the government under government contracts. No one can quarrel with this basic thinking since improvements that result under government contracts have been developed with the taxpayers' money and should be readily available for use to meet the country's needs. Under cost plus fixed fee contracts such engineering work is paid for under what is generally agreed to be a questionable formula.

In the course of completing a contract, the components manufacturer accepts the implied responsibility to achieve certain electrical objectives, although he may be working to mechanical measurements. At the expense of the manufacturer an engineer is put to work to solve any electrical problems in connection with a production contract that may be involved; but the subcontractor is not reimbursed for such engineering costs. Let's suppose that the engineer discovers something of real value and, accordingly, the drawings are corrected; the final unit manufactured performs better electrically, and meets the requirements of the customer.

This engineering expense comes out of the manufacturer's pocket, whereas when engineering is done under a development contract, payment is made for the engineering, per se. The components manufacturer is in a rather peculiar position, i.e., there isn't any possibility of recovering his engineering costs and he is required to reveal improvements he has made to the customer. The prime contractor often is not in a position to recompense him, as he may lose out when the contract is thrown open for public bidding again.

The Government also insists that new design improvements go into the blueprints for contract production jobs

*(Continued on page 46)*

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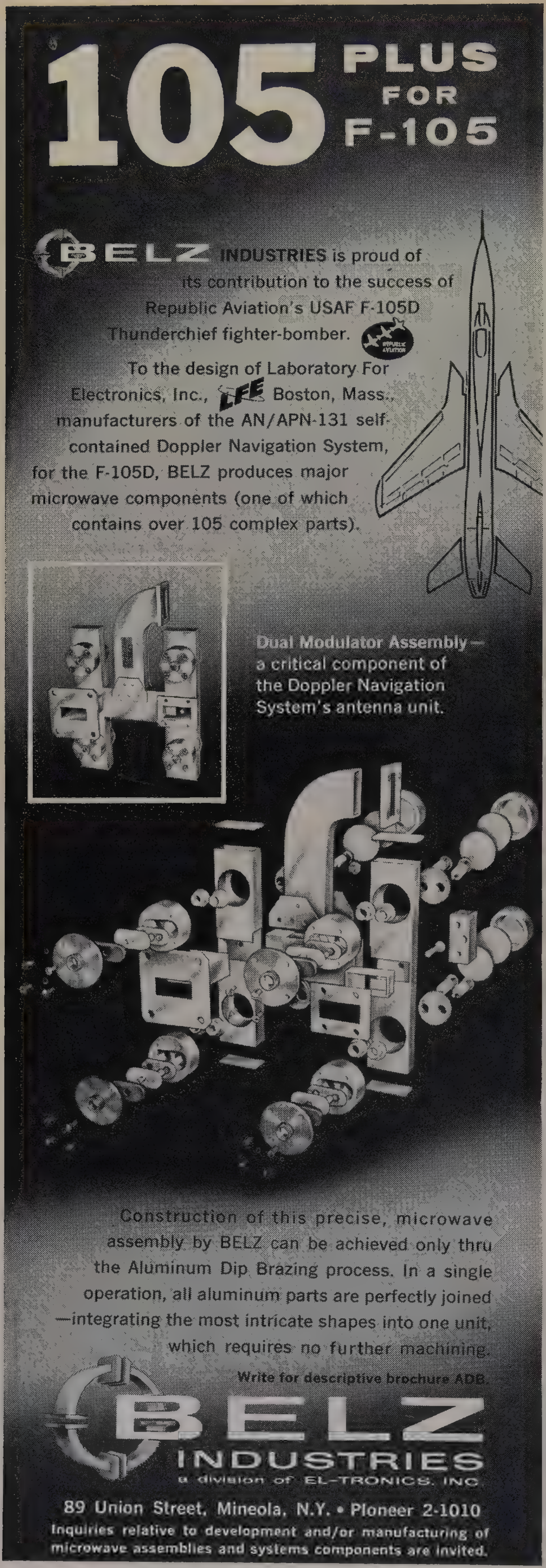
**IRVING M. GROSS**, president of the Portchester Instrument Corporation, has been engaged in architecture, engineering design, general contracting and a handful of other unrelated activities.

His entry into electronics came as a direct result of his general contracting and construction activities. In 1942, Mr. Gross built a plant for a microwave corporation in downtown New York, and he later took over operation of the new plant.

In 1953 he set up the Portchester Instrument Corporation to specialize in microwave work for telephone link communication.

Mr. Gross is chairman of the Industrial Division of the Chamber of Commerce in Rye and Port Chester and a director of the City Affairs Committee of New Rochelle.



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## GROSS

*(Continued from page 45)*

and, therefore, every production shop has an equal chance to bid for the contract. The thinking behind this is to make certain no one manufacturer is favored and that the Government gets the best production price possible.

It is doubtful that anyone would argue the propriety of these government limitations, especially if provision were made for adequate incentive to the various groups which contribute to the advancement of the art. However, as with many other statements of generalized policy, there are flaws here that severely penalize the over-all forward movement of the industry and may well have a depressant effect on the industry's future development.

The first of these flaws, and perhaps the most serious in the long run, is that many small component manufacturers are turning away from engineering and development work to concentrate solely on production contracts, which are more profitable. When this happens, these manufacturers lose the stimulation and the benefits that come from engineering and development work. They do not use their creativity to keep the industry up to date and progressing. They become classified as strictly production outfits and find the door to development funds closed to them.

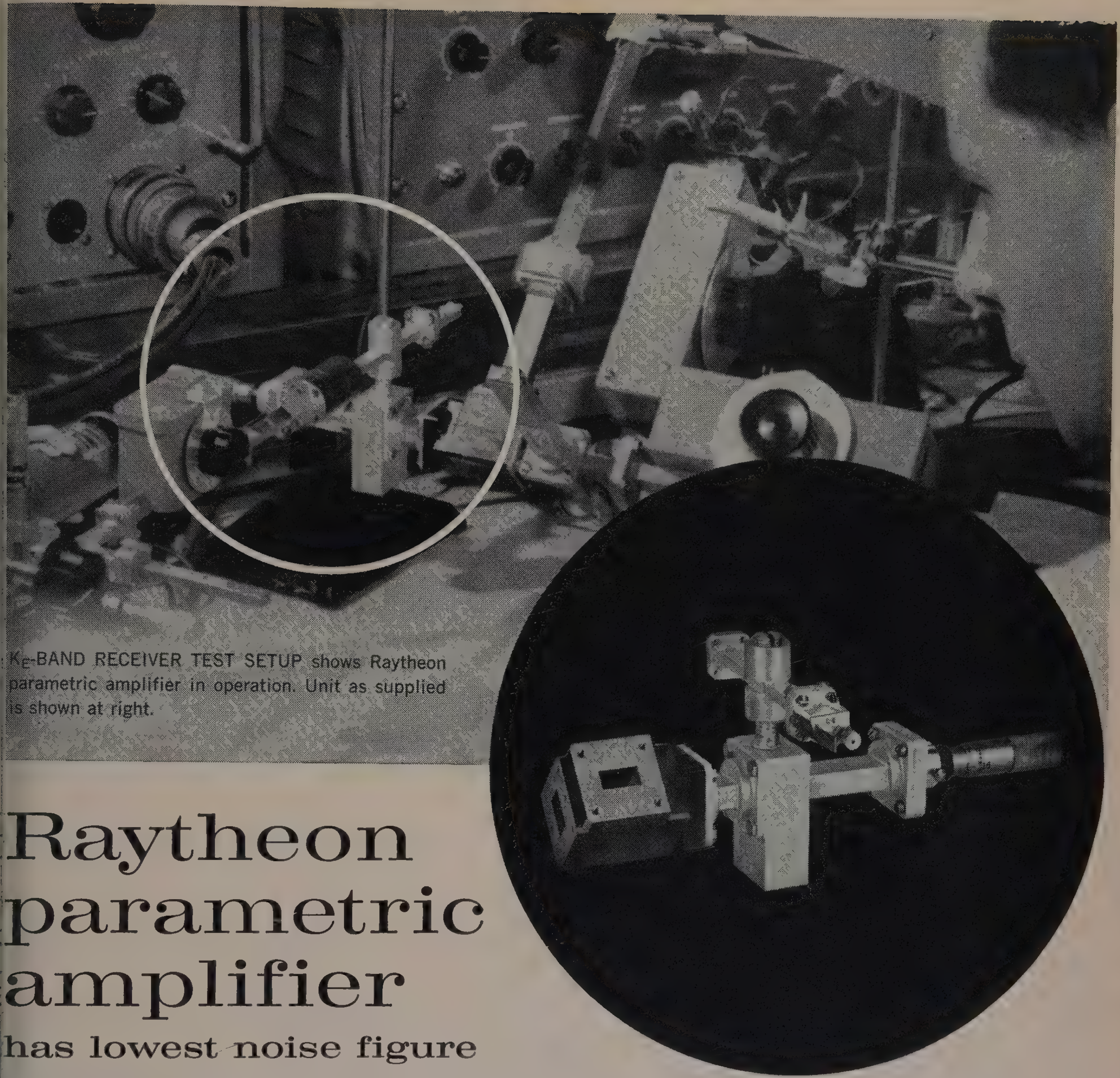
What effect does this have? Obviously, the industry has lost the skills, the ability and the ingenuity of these people. It has wasted a portion of its human resource of professional talent that is so vital to the progress of modern microwave technique. The nation has sacrificed scientific potential for productive potential simply because the financial motivation to stimulate competition of bidders stifles competition for in-process improvement of product.

The second of these flaws is that the engineering and development money that is available usually goes to the prime contractor and can seldom filter down to the component manufacturer Yet component companies cumulatively make sizeable contributions to the success of the prime contract through engineering improvements, without securing a corresponding advantage in bidding for the production part of the job. In fact, a straight production outfit often can put in a lower bid because it has not been handicapped in its thinking by the need for recovering engineering expense and overhead.

Let's see how this works out in practice. The development of the microwave industry has been very rapid. Products and designs become obsolete very quickly as new breakthroughs occur. This, in itself, is a natural evolution of a growing art which is in its infancy. But it does mean that an individual manufacturer stands very little chance of recovering development costs on improved design — it becomes obsolete too fast. Further improvements on the design made by others negate its value completely in a very short period.

Here's an example. A space limitation on a unit precluded the use of a standard cavity in the assembly. So the manufacturer set out to miniaturize the cavity. As a result a new cavity was developed about one-fifth the size, ten per cent of the weight and one-fifth the cost of

*(Continued on page 48)*



$K_E$-BAND RECEIVER TEST SETUP shows Raytheon parametric amplifier in operation. Unit as supplied is shown at right.

# Raytheon parametric amplifier

## has lowest noise figure yet reported at $K_E$ band

**New degenerate amplifier has noise figure of 3 db with double sideband signal**

This parametric amplifier offers a greater signal-to-noise advantage than any yet announced for 13.5 kMc operation. The model described here is ideally suited for application as a pre-amplifier in MTI radar receivers. However, Raytheon can supply units with comparable performance at other frequencies to meet your particular requirement.

Write today for details on this or other Raytheon developments in microwave devices. Special Microwave Devices Operation, Raytheon Company, Waltham Industrial Park, Waltham, Massachusetts.

| TYPICAL SPECIFICATIONS | |
|---|---|
| Mode of Operation | Degenerate |
| Signal Frequency | 13.5 kMc |
| Pump Frequency | 27 kMc |
| Noise Figure (double sideband) | 3 db max. |
| Gain | 17 db min. |
| Bandwidth | 10 Mc min. |
| Tunability of Amplifier | 10% min. |
| Typical Pump Power<br>(Function of Diode) | 50 mw max. |
| Weight (includes 6 oz. circulator) | 2.0 lbs. |

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RAYTHEON COMPANY

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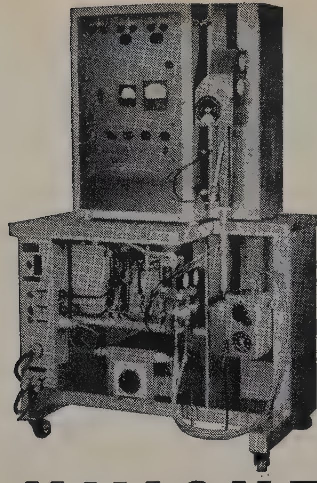

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## GROSS

*(Continued from page 46)*

the device previously used. At the same time better electrical performance was achieved.

Then what happens? The blueprints of this improvement go out to all qualified bidders and the production contract is awarded solely on the basis of price. If the product-developer bids high enough to recover the necessary engineering investment that made the improvement possible, he will undoubtedly lose out completely. If he bids solely on the production demands, he may get the production contract but he will not be compensated for the costs involved in making the technical improvement.

This, I submit, should be remedied. As long as this practice continues, the Government, the prime contractor, the small companies and the general public, will lose. Therefore, I think it is up to the industry to attempt to find a solution and take the necessary initiative to bring this problem and its possible solutions to the attention of the Government.

The basis for such policy reform is that the microwave field is uniquely a group of specialists. The small manufacturers are the specialists. The prime contractors are most often generalists. Each component in the assembly is made by a specialist who has spent years of devotion, interest and study in his particular contribution to the whole. It is mainly at the component manufacturing level that this degree of specialization can be found.

Now what can be done? What are some of the possible solutions to the problem? One possible avenue of approach is through the Small Business Administration (SBA). We in the microwave field have not taken full advantage of the facilities of this government body.

The SBA is set up primarily to channel government funds so that production is divided between the large corporations and the smaller companies. Certainly it should be an SBA responsibility to see that part of the development funds that go to the larger companies is distributed more widely to the smaller manufacturers and that this development money is used to advance the state of the art at the small business level.

Perhaps the average microwave manufacturer is partly to blame that this has not been done sooner. Actually, we have had little or no contact with SBA because we normally deal with prime contractors rather than directly with the Government. Regardless of the specific limitations of SBA, it is our understanding that at least some Department of Defense contracts are restricted to small business only. Certainly, in the engineering and development area, this philosophy could be made to work through prime contractors down to the component manufacturers.*

Let's draw a parallel with the music business. The American Society of Composers, Authors and Publishers (ASCAP) sees to it that a creator of a piece of music gets paid for it. Before ASCAP came into being, a composer

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**The government presently fixes and allots to small business a definite percentage for production work on the prime contract. By extending this formula, perhaps a smaller percentage for development work and engineering could be allotted which would achieve a more equitable distribution.*

*(Continued on page 50)*

*Hughes TWT capability offers you*

# New solutions for tube and systems problems

A continuing program of applied research by Hughes has resulted in the development of outstanding operating features such as those illustrated in the accompanying cutaway of a high-powered TWT.

When *you* have a requirement for an advanced microwave tube—CW or pulsed—consider TWT's, and Hughes. Perhaps the solution to your problem is already in development, or *production*, at Hughes.

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**HUGHES**

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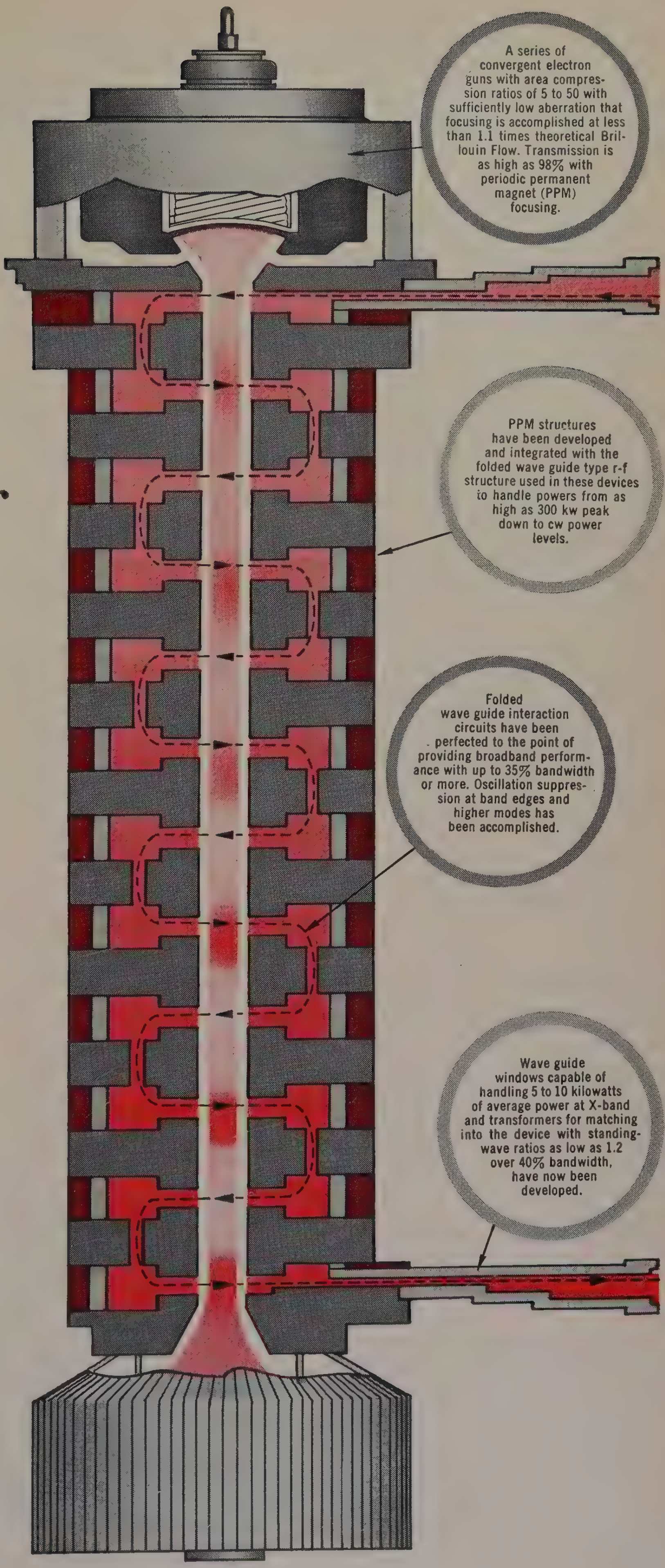
**MICROWAVE TUBE DIVISION**



A series of convergent electron guns with area compression ratios of 5 to 50 with sufficiently low aberration that focusing is accomplished at less than 1.1 times theoretical Brillouin Flow. Transmission is as high as 98% with periodic permanent magnet (PPM) focusing.

PPM structures have been developed and integrated with the folded wave guide type r-f structure used in these devices to handle powers from as high as 300 kw peak down to cw power levels.

Folded wave guide interaction circuits have been perfected to the point of providing broadband performance with up to 35% bandwidth or more. Oscillation suppression at band edges and higher modes has been accomplished.

Wave guide windows capable of handling 5 to 10 kilowatts of average power at X-band and transformers for matching into the device with standing-wave ratios as low as 1.2 over 40% bandwidth, have now been developed.

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## GROSS

*(Continued from page 48)*

was never sure of collecting anything for his work. People realized it was wrong for the man who wrote Swanee River to die in a Bowery flophouse. Now, every time a record is played — or a piece of music performed for profit — the composer gets a reward.

Then why shouldn't a corporate "individual" who makes an important contribution to the microwave industry get some reward? A reward that should certainly cover his costs in achieving the improvement, and preferably enough more to provide a continued incentive to seek such rewards. Under the present situation, such a company is at a disadvantage because if it tries to recover its costs, the production price is too high.

If the Government is to effectively promote and stimulate scientific engineering development research skills on the level where they can be found, some provision for compensation for progress must be made. Most of the microwave research skill is found on the small company level, particularly when we refer to components improvement.

Another way to tackle this problem is to make sure the manufacturer who makes the innovation, or development, or improvement, gets credit for it. At present, the credit most often goes to the prime contractor. The subcontractor gets little or no recognition for his creative work and, as a result, is often discouraged from further efforts.

A nation that awarded its highest medal to honor George M. Cohan for his contribution in writing patriotic songs, certainly can find methods to recognize properly the major contributions being made by the engineering and development teams of small industry. Perhaps we need a government honors program or a special medal or awards system. The microwave industry, in cooperation with the proper government officials, should start thinking about this.

This last suggestion is, of course, a rather poor second to the idea of simply letting people be reasonably compensated. After all, this is the basis of our entire economic system. While no one wants such compensation to be excessive, it should be enough to "pay the way" for this type of work.

Everyone who ventures into the engineering and development area in microwave work is either heir to or victim of any change in originality, ingenuity or inventiveness. Progress is made quickly in this field. Unless the rewards for progress are more widely distributed, the art will suffer.

The responsibility to solve industry problems such as this lies with the industry itself. It is not up to the Government alone, or the prime contractor, to come to the small company with an answer. It is up to those of us on the small company executive level to analyze these problems as they affect us, find practical and workable solutions and see that our suggestions receive serious consideration at the proper level in industry and Government. It is to be hoped that the component manufacturers will actively face the challenge of adequate compensation for their contributions in engineering and development work promptly and forcefully.

The future of our industry and much of our national defense is directly affected by our continued procrastination.

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## Industry News

*(Continued from page 42)*

### GE AWARDED CONTRACT FOR PRODUCTION OF SEARCH RADARS

A $5,301,957 contract for the production of advanced high power, search radars for air defense has been awarded to the General Electric Co., according to an announcement by Robert J. Brown, General Manager of the Company's Heavy Military Electronics Department, Syracuse, N. Y.

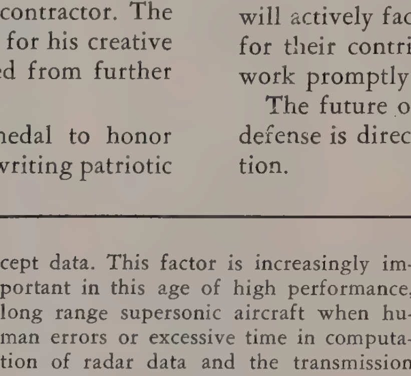
The new contract from the USAF Air Logistics Command's Rome Air Materiel Area is a follow-on order to a $6,814,675 contract announced late last year.

Designated the AN/FPS-7, this high power, multi-beam search radar is capable of detecting aircraft at significantly higher altitudes and longer ranges than present day air defense radars. It will supply radar data to the SAGE Continental Air Defense System.

Mr. Brown said that the FPS-7 provides much faster target data on approaching aircraft than is possible with the conventional system using separate radars for obtaining range and height. In the FPS-7 this data is relayed to the computers at the same time, eliminating the present interdependency of one radar on another and speeding up the calculation of intercept data. This factor is increasingly important in this age of high performance, long range supersonic aircraft when human errors or excessive time in computation of radar data and the transmission of weapon control commands could be disastrous.

*—mwj—*

### MICROWAVE COMMUNICATION SYSTEM DEVELOPED BY COLLINS RADIO



Protection from over-pressure ground shock waves up to 25 psi and automatic fault-sensing and re-route switching are the most novel features of a toughened microwave communication system recently completed for the Fairchild Atlas complex by Collins Radio Company, Dallas, Tex.

The system is capable of providing a total of 480 3-kc voice channels to serve the widely dispersed launch sites and the command post control center at SAC's Fairchild AFB near Spokane, Washington.

A total of 862 channel ends are currently being utilized for channels carrying the various command and control circuits. The multiplex system is Collins MX-103 carrier deriving single sideband suppressed carrier channels which are frequency synchronized. The system is expandable to 600 voice channels. Fault alarm and automatic switching circuits are provided exclusive of the voice multiplex.

Equipment racks at each site are installed on specially designed shock-mounts 20 feet underground in concrete and steel bunkers. Four-foot antennas used for most terminals are mounted in concrete pedestals and protected by high strength 3/4 inch thick plastic radomes electrically transparent.

*—mwj—*

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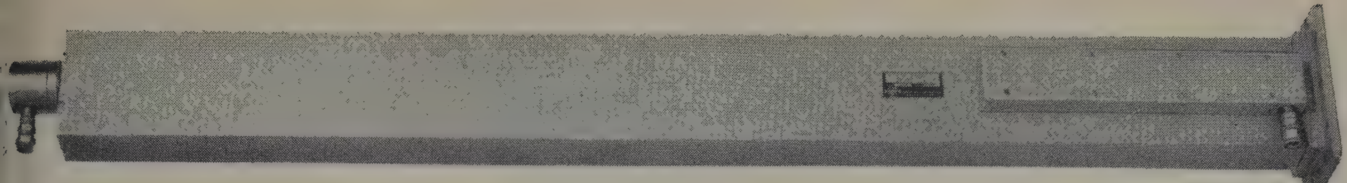
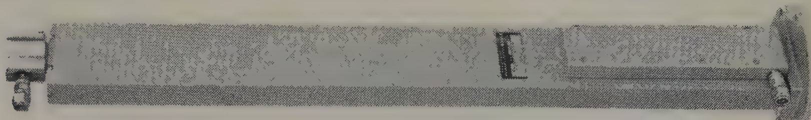
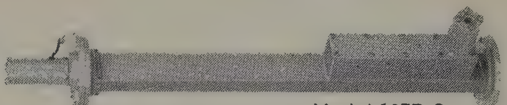
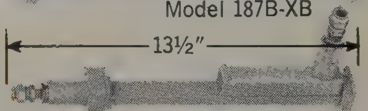

Model 187B-SL

# COMPLETE LINE OF VERSATILE, EFFICIENT WAVEGUIDE WATER LOADS


Model 187B-S


Model 187B-C

Model 187B-XB



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## for SL, S, C, XB and X Frequency Bands

- Five models covering five bands
- Three models useful in pressurized systems
- VSWR less than 1.10
- Can handle 2-20 kw average power
- Low rf radiation
- Calibration heaters in all models

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## CHECK ALL THESE SPECIFIED ADVANTAGES!

| Model Number: | 187B-SL | 187B-S | 187B-C | 187B-XB | 187B-X |
|---|---|---|---|---|---|
| Frequency Range: | 1.7 to 2.6 kmc | 2.6 to 4.0 kmc | 5.8 to 8.2 kmc | 7.0 to 10.0 kmc | 8.2 to 12.4 kmc |
| VSWR: | < 1.10 to 2.4 kmc<br>< 1.15 to 2.6 kmc | less than 1.10 | less than 1.10 | less than 1.10 | less than 1.10 |
| Power Average: (Unpressurized) | 20 kw | 10 kw | 5 kw | 3 kw | 2 kw |
| Peak Power: | 2 megawatts | 1 megawatt | 500 kw | 250 kw | 150 kw |
| Max. Air Pressure: | * | * | 45 psig | 45 psig | 45 psig |
| Waveguide: | RG-105/U | RG-75/U | RG-50/U | RG-51/U | RG-52/U |
| Connector: | UG-437A/U | UG-584/U | UG-344/U | UG-51/U | UG-39/U |
| Recommended Water Flow: | 2 gpm for 10 kw | 2 gpm for 10 kw | 1 gpm for 5 kw | 0.6 gpm for 3 kw | 0.4 gpm for 2 kw |
| Pressure Drop at Rated Flow: | 10 psi | 10 psi | 10 psi | 10 psi | 10 psi |
| Max. Water Pressure: | 80 psig | 80 psig | 80 psig | 80 psig | 80 psig |
| Water Temperature: | 0 to 70° C | 0 to 70° C | 0 to 70° C | 0 to 70° C | 0 to 70° C |
| Water Capacity: | 18.5 cu. in. | 3.5 cu. in. | 0.85 cu. in. | 0.42 cu. in. | 0.20 cu. in. |
| Water Renewal at Rated Flow: | Once per 2.5 sec. | 2 times per sec. | 4.3 times per sec. | 5.3 times per sec. | 7.4 times per sec. |
| Heater Resistance: | 4.5 ohms | 9 ohms | 14 ohms | 20 ohms | 20 ohms |
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| Length: | 50 in. | 32 in. | 20 in. | 17.25 in. | 13.5 in. |
| Price: | $600.00 | $500.00 | $425.00 | $400.00 | $375.00 |

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For complete details, see your Sierra Representative or write direct.

*NEW!* Sierra also offers its Model 186 Series Coaxial Water Loads, covering dc to 4 kmc.

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*A Division of Philco Corporation*

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Sales representatives in all principal areas

Canada: Atlas Instrument Corporation, Ltd., Montreal, Ottawa, Toronto, Vancouver

Export: Frazar & Hansen, Ltd., San Francisco, Los Angeles

6807

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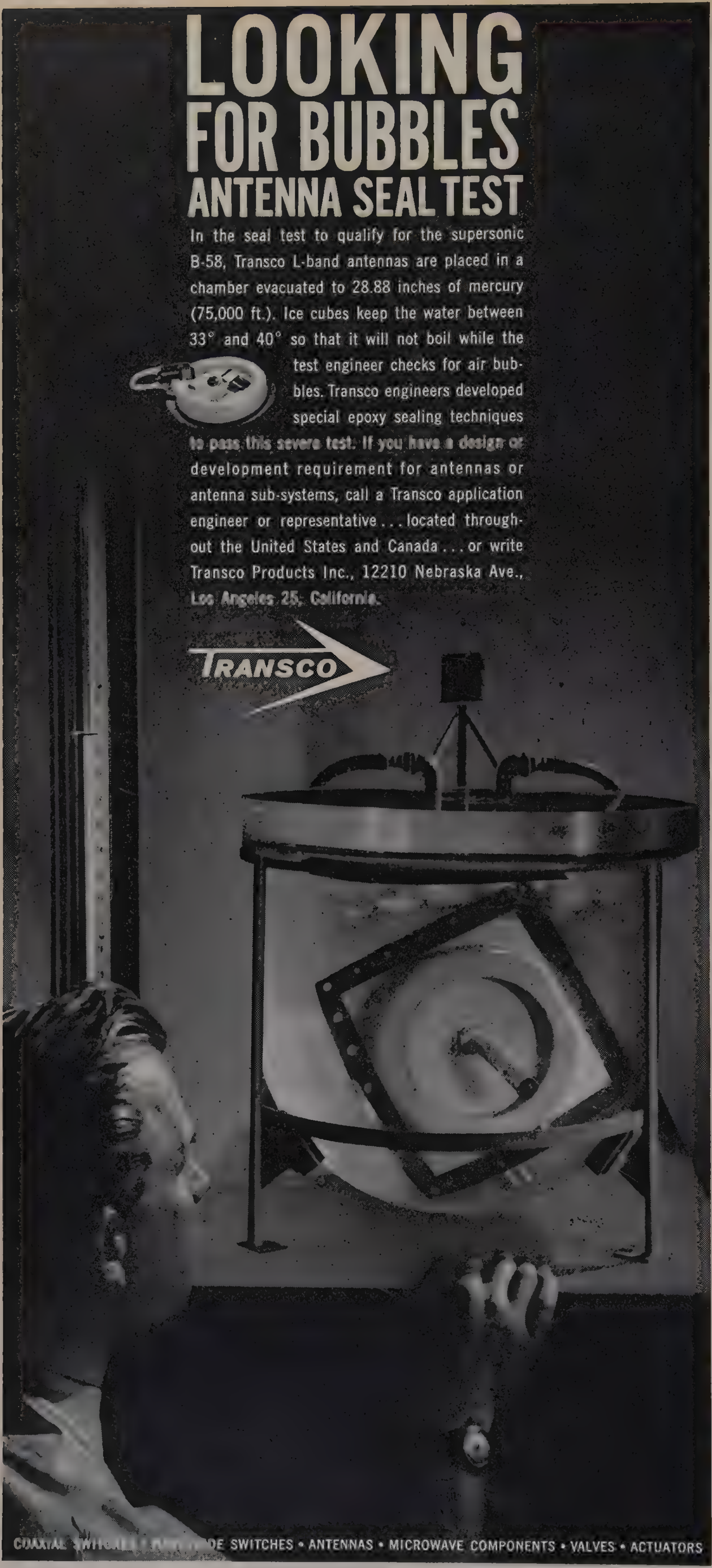


LOOKING FOR BUBBLES
ANTENNA SEAL TEST

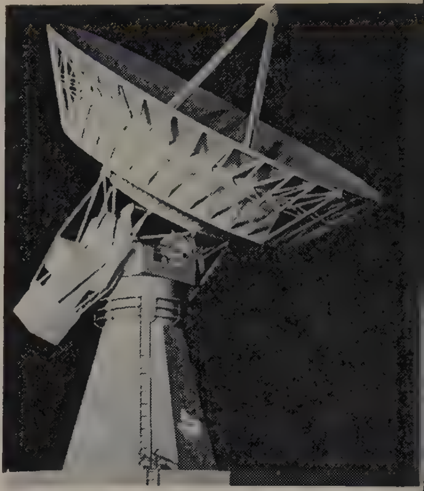
In the seal test to qualify for the supersonic B-58, Transco L-band antennas are placed in a chamber evacuated to 28.88 inches of mercury (75,000 ft.). Ice cubes keep the water between 33° and 40° so that it will not boil while the test engineer checks for air bubbles. Transco engineers developed special epoxy sealing techniques to pass this severe test. If you have a design or development requirement for antennas or antenna sub-systems, call a Transco application engineer or representative . . . located throughout the United States and Canada . . . or write Transco Products Inc., 12210 Nebraska Ave., Los Angeles 25, California.

TRANSCO

COAXIAL SWITCHES • WAVEGUIDE SWITCHES • ANTENNAS • MICROWAVE COMPONENTS • VALVES • ACTUATORS

*(Continued from page 50)*

### GT&E RECEIVES PROJECT ADVENT CONTRACT



Receipt of a $1.2 million contract extension award for ground stations for the U. S. Army's ADVENT communications satellite program near Fort Dix, N. J., and Camp Roberts, Cal., has been announced by General Telephone & Electronics Corporation. Sylvania Electric Products Inc., Waltham, Mass., subsidiary of GT&E, is responsible for the development, fabrication, and installation of all operations facilities.

Project ADVENT is aimed at developing a military capability for instantaneous world-wide microwave communication through hovering satellites operating in 24-hour synchronous orbit. By orbiting 22,300 miles above the equator in the same direction and at the same angular velocity as the earth's rotation, each of the ADVENT satellites would appear to remain stationary overhead.

The satellites would receive and amplify radio signals from one ground station and re-transmit them to another ground station. The work is under the administrative and technical management of the U. S. Army ADVENT Management Agency, Fort Monmouth, N. J., and under the technical direction of the U. S. Army Signal Research and Development Laboratory at Fort Monmouth. The $1.2 million contract extension brings total Sylvania awards on the program to approximately $3.6 million.

*— m w j —*

### MARCUVITZ NAMED DEAN OF BROOKLYN TECH GRADUATE CENTER

Dr. Nathan Marcuvitz, professor of electrophysics and vice president for research at the Polytechnic Institute of Brooklyn, has been named acting dean of Polytechnic's Long Island Graduate Center in Farmingdale, it was announced by Dr. Ernst Weber, president.

*(Continued on page 54)*

Circle Reader Service Card 39

## Philco Solid-State X-Band Switches can

# MODERNIZE THESE 8 MICROWAVE CONCEPTS

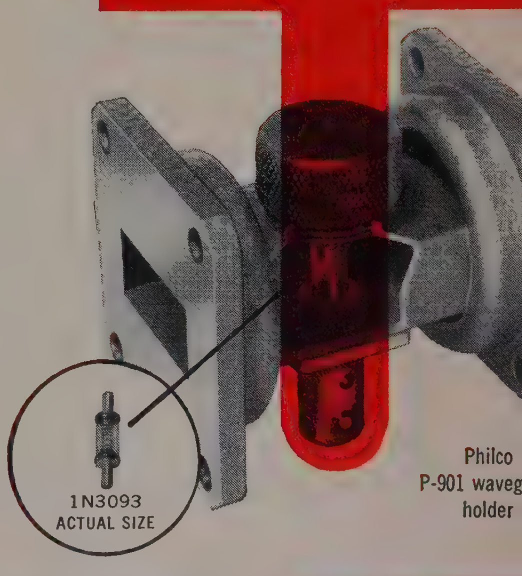
- Electronically Steerable Antennae
- Microwave Channel Switching
- Microwave Modulators
- Voltage Controlled Microwave Attenuators
- Microwave Pulse Shapers
- Microwave Limiters
- Microwave Clippers
- Direct Switching of Transmitter and Receiver Power

Solid-state design is an apparent trend in microwave equipment. The inherent advantages are solid-state reliability, smaller size, lighter weight, lower power requirements, less auxiliary components . . . and Philco X-Band Germanium switching crystals help make this trend possible.

Philco types 1N3093, 1N3481, and 1N3482 have several unique features. They exhibit total switching times as short as 1 nanosecond. These three types can be intermixed in cascade to provide extremely high isolation values . . . without unduly sacrificing insertion loss or power handling capability. They serve as frequency-independent switches between DC and 1 Gc. Virtually *any* application requiring rapid and predictable control or modification of microwave power flow can utilize these diode switches.

Though ratings shown on this page are based on mounting in a commercially available Philco P-901 waveguide holder, Philco X-Band switching crystals also are suited to coaxial transmission designs.

| **ABSOLUTE MAXIMUM RATINGS** | **1N3481** | **1N3093** | **1N3482** |
|---|---|---|---|
| Storage Temperature.... | −65 to +90°C | −65 to +90°C | −65 to +90°C |
| Forward Current........ | 60 ma | 85 ma | 100 ma |
| Reverse Current........ | 5 ma | 10 ma | 10 ma |
| Peak Microwave Incident Power Level.......... | 10 mw | 500 mw | 1.25 w |
| **ELECTRICAL CHARACTERISTICS** | | | |
| Test Conditions (T=25°C) | | | |
| Test Frequency......... | 9000 mc | 9000 mc | 9000 mc |
| Power Level............ | 1 mw | 500 mw | 1.25 w |
| Test Holder............ | Philco P-901 | Philco P-901 | Philco P-901 |
| Dynamic Characteristics | | | |
| Insertion Loss.......... | (I = +50 ma)<br>Typ. Max.<br>0.75 1.0db | (I = +75 ma)<br>Typ. Max.<br>1.6 1.8db | (I = +100 ma)<br>Typ. Max.<br>2.0 2.3db |
| Isolation................ | (V = −0.5v)<br>Min. Typ.<br>18 21db | (V = −11v)<br>Min. Typ.<br>18 21db | (V = −11v)<br>Min. Typ.<br>18 20db |



For complete data and application assistance,
write Dept. MJ861. **SPECIAL PRODUCTS OPERATION**

*Immediately available from your Philco Industrial Semiconductor Distributor*

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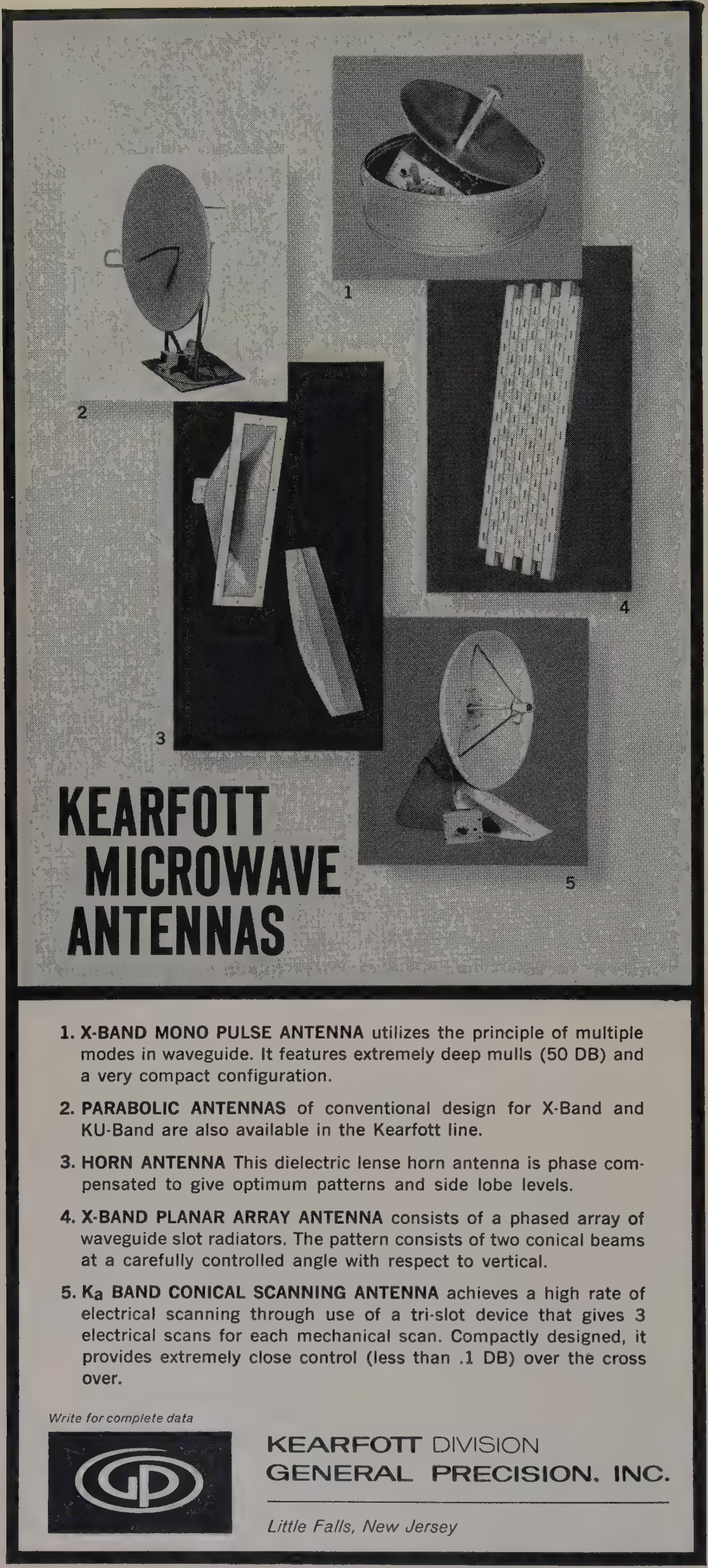
**LANSDALE DIVISION • LANSDALE, PENNSYLVANIA**

**IN EUROPE: Avenue de Beauregard 3, Fribourg, Switzerland**



KEARFOTT MICROWAVE ANTENNAS

1. **X-BAND MONO PULSE ANTENNA** utilizes the principle of multiple modes in waveguide. It features extremely deep mulls (50 DB) and a very compact configuration.
2. **PARABOLIC ANTENNAS** of conventional design for X-Band and KU-Band are also available in the Kearfott line.
3. **HORN ANTENNA** This dielectric lense horn antenna is phase compensated to give optimum patterns and side lobe levels.
4. **X-BAND PLANAR ARRAY ANTENNA** consists of a phased array of waveguide slot radiators. The pattern consists of two conical beams at a carefully controlled angle with respect to vertical.
5. **K$_a$ BAND CONICAL SCANNING ANTENNA** achieves a high rate of electrical scanning through use of a tri-slot device that gives 3 electrical scans for each mechanical scan. Compactly designed, it provides extremely close control (less than .1 DB) over the cross over.

*Write for complete data*

KEARFOTT DIVISION
GENERAL PRECISION, INC.

*Little Falls, New Jersey*

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## Industry News

*(Continued from page 52)*

Dr. Marcuvitz was director of Polytechnic's Microwave Research Institute until his appointment as research vice president earlier this year.

As acting dean, the 47-year-old electrophysicist will coordinate the academic planning and the basic research programs attendant on the masters and doctors programs. He retains his post as vice president for research.

Dr. Marcuvitz received his bachelors, masters and doctors degrees in electrical engineering from the Polytechnic. He worked as a development engineer for the Radio Corporation of America (1936-1940) and served as a graduate fellow at the Polytechnic (1940-1941).

Dr. Marcuvitz is a fellow of the Institute of Radio Engineers, and a member of the American Physical Society, Tau Beta Pi, Eta Kappa Nu, and Sigma Xi.

— *mwj* —

### TRG ADDS PLANT FOR ANTENNA AND MICROWAVE DEVELOPMENT

Dr. Alan F. Kay, vice president, Technical Research Group Inc., Somerville, Mass., has announced the purchase of a new plant in East Boston, Mass. The new 25,000 square foot facility, in addition to the present Somerville location, will be used by the Antenna and Microwave Department.

The Antenna and Microwave Department of TRG, Inc., has been engaged in antenna research and prototype production since 1953, and in research and production of millimeter microwave components since 1957. The new plant will be used for large precision antenna and microwave projects, thus enabling TRG to play a major role in the antenna subassembly field; other fields of activity include radio and optical frequency spectroscopy, and navigational and simulation equipment and systems.

The new facility features a 60 foot x 160 foot antenna erection and test area; 10 ton bridge crane; truck and dockside shiploading facilities; 34 foot stud height; controlled heating throughout which is important for precision fabrication.

Mr. Gerald Brown has been appointed general manager of the new facility. Mr. Brown was formerly chief engineer of the Diamond Antenna & Microwave Corp. Mr. Bruno Pawlowski has been appointed chief engineer. He was formerly chief engineer and engineering marketing manager at Gabriel Corp.

— *mwj* —

*(Continued on page 56)*

# NOW!

## MAKE PRECISION

# Attenuation Measurements

## WITH THE NEW

# SPERRY *Microline*®

## MODEL 61A1

## PARALLEL I-F SUBSTITUTION RECEIVER SYSTEM

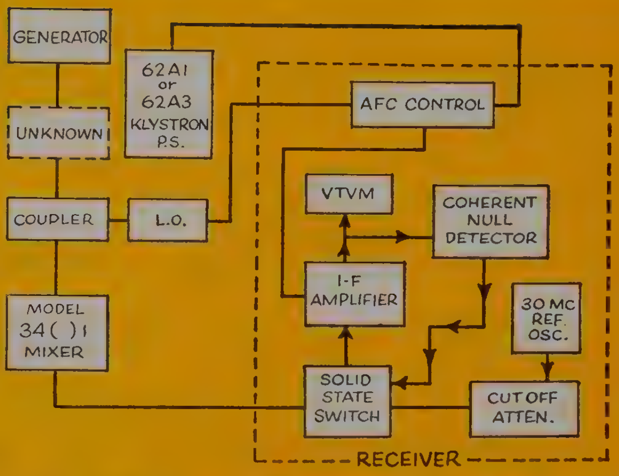
Now your laboratory can make precision attenuation measurements over dynamic ranges of 100 db with the new Microline Model 61A1 Parallel I-F Substitution Receiver System. It has these outstanding advantages:

1. Accuracy of .005 db per db, and readout resolution of .02 db
2. No preamp required for full 100 db dynamic range
3. Linear or log operation
4. Completely adaptable AFC circuitry for klystron or BWO
5. Ultra-stable 30 mc reference oscillator
6. Precision cut-off attenuator
7. Receiver noise figure of 3 db

Extreme accuracy is obtained through comparison of the test signal with the parallel substitution signal made by a solid state I-F input switch and output coherent null detector. No special RF plug-in heads are required. Accessory mixers and local oscillator couplers are available from 2.6 through 40 GC. (See table below).

Further information on request.

**Microline 61A1**
**Microwave Receiver**



**MULTIHOLE COUPLERS**

Directivity is greater than 40db, frequency sensitivity less than ±0.5db on all units

| MODEL | FREQUENCY (GC) | AVERAGE COUPLING (db) | PRICE |
|---|---|---|---|
| 45S1 | 2.60- 3.95 | 3, 10, 20 | $375 |
| 45C1 | 3.95- 5.85 | 3, 10, 20 | $250 |
| 45G1 | 5.85- 8.20 | 3, 10, 20 | $140 |
| 45H1 | 7.05-10.00 | 3, 10, 20 | $120 |
| 45X1 | 8.20-12.40 | 3, 10, 20 | $100 |
| 45U1 | 12.40-18.00 | 3, 10, 20 | $115 |
| 45K1 | 18.00-26.50 | 3, 10, 20 | $175 |
| 45V1 | 26.50-40.00 | 3, 10, 20 | $200 |

**TUNABLE DETECTOR MOUNTS**

| MODEL | FREQUENCY (GC) | PRICE |
|---|---|---|
| 34B2 | 1.00-11.00 | $ 75 |
| 34S1 | 2.60- 3.95 | $180 |
| 34C1 | 3.95- 5.85 | $ 95 |
| 34G1 | 5.85- 8.20 | $ 90 |
| 34H1 | 7.05-10.00 | $ 85 |
| 34X1 | 8.20-12.40 | $ 75 |
| 34U1 | 12.40-18.00 | $160 |
| 34K1 | 18.00-26.50 | $170 |
| 34V1 | 26.50-40.00 | $180 |

SPERRY

**SPERRY MICROWAVE ELECTRONICS COMPANY,** *CLEARWATER, FLORIDA • DIVISION OF SPERRY RAND CORPORATION*

**Microline Instruments** • *Radar Test Sets • Systems Instrumentation • Solid State Devices and Materials • Microwave Components and Antennas*

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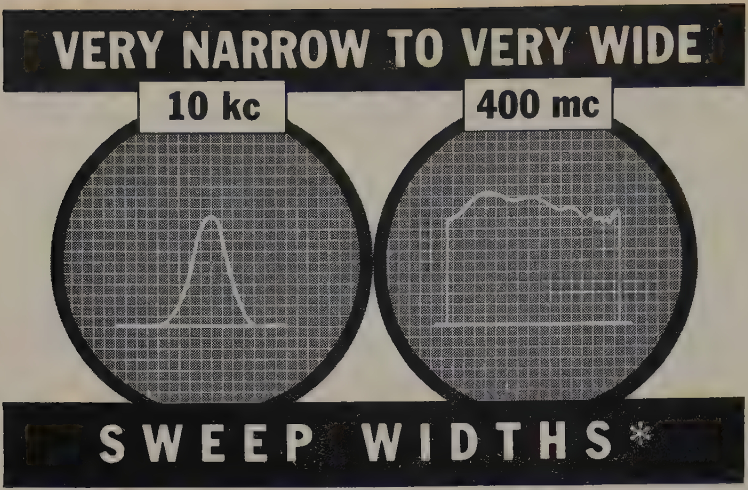

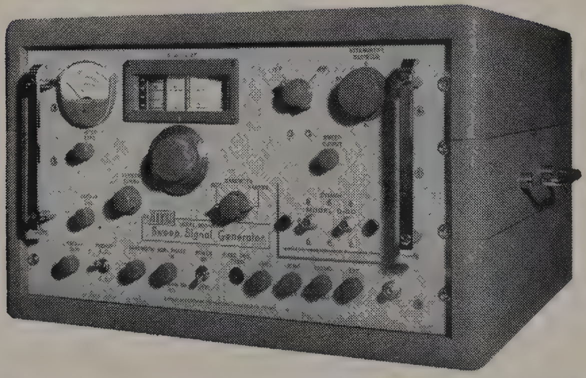

**...ALL IN ONE INSTRUMENT**

NEW JERROLD® 900B

**SWEEP SIGNAL GENERATOR**

Here's the last word in versatility and precision, the ultimate instrument for all your IF-VHF-UHF requirements. The new Jerrold 900B offers unusual stability in sweep widths as narrow as 10 kc and as wide as 400 mc. Frequency range 500 kc to 1200 mc.

$1980.00 *f.o.b. Philadelphia***

*Illustration of scope at left shows typical communications receiver response 4 kc bandwidth at 7 mc. Illustration at right shows typical distributed amplifier response 2-220 mc.

***Prices and specifications subject to change without notice.*

- **Built-in crystal-controlled harmonic markers at 1, 10, and 100mc intervals.**
- **Each marker output individually controls from front panel.**
- **Built-in variable-gain dc-coupled scope preamplifier with 200X gain.**
- **Built-in precision attenuator from zero to 50db in 10db steps.**
- **Accurately calibrated frequency dial.**
- **High-level metered output.**

*Write for complete technical data.*

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**The Jerrold Building, Philadelphia 32, Pa.**

*Jerrold Electronics (Canada) Ltd., Toronto •*
*Export Representative: Rocke International, New York 16, N.Y.*

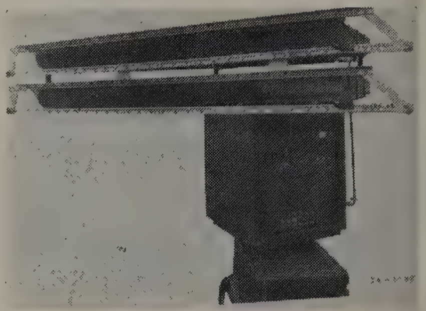
WESCON BOOTHS 1002-1004

**Circle Reader Service Card 43**

## Industry News

*(Continued from page 54)*

### HIGH RESOLUTION RADAR MAKES USE OF CIRCULAR POLARIZER



A high resolution millimeter wave radar capable of seeing objects as small as buoys, bamboo net poles, spars and life rafts during severe storms has been announced by Tokyo Shibaura Electric Co. (Toshiba).

The radar was designed for use along inland waterways and coastal harbors, and as Airport Surface Detection Equipment (ASDE) and other traffic control areas. Heading the development project were A. Kurokawa, chief radar engineer and T. Yamanaka, engineer in charge of Avionics Techniques.

The company, a leader in electronic research and development work in Japan, was the first to experiment successfully in that country with a circular polarizer MM wave radar.

Use of a circular polarizer and a MM wave length results in a maximum detectable range of eight nautical miles. Range resolution between two vessels is four meters at one nautical mile on the 1.5 nautical mile range of a 12 inch radar screen. The bearing resolution between two ships is 15 minutes on a four mile range. The range and bearing resolution between a buoy and ship are similar.

—*mwj*—

### MICROWAVE ASSOCIATES RECEIVES OVER $700,000 IN CONTRACTS

Microwave Associates, Inc., Burlington, Mass., announces the receipt of new contracts totaling more than $700,000.

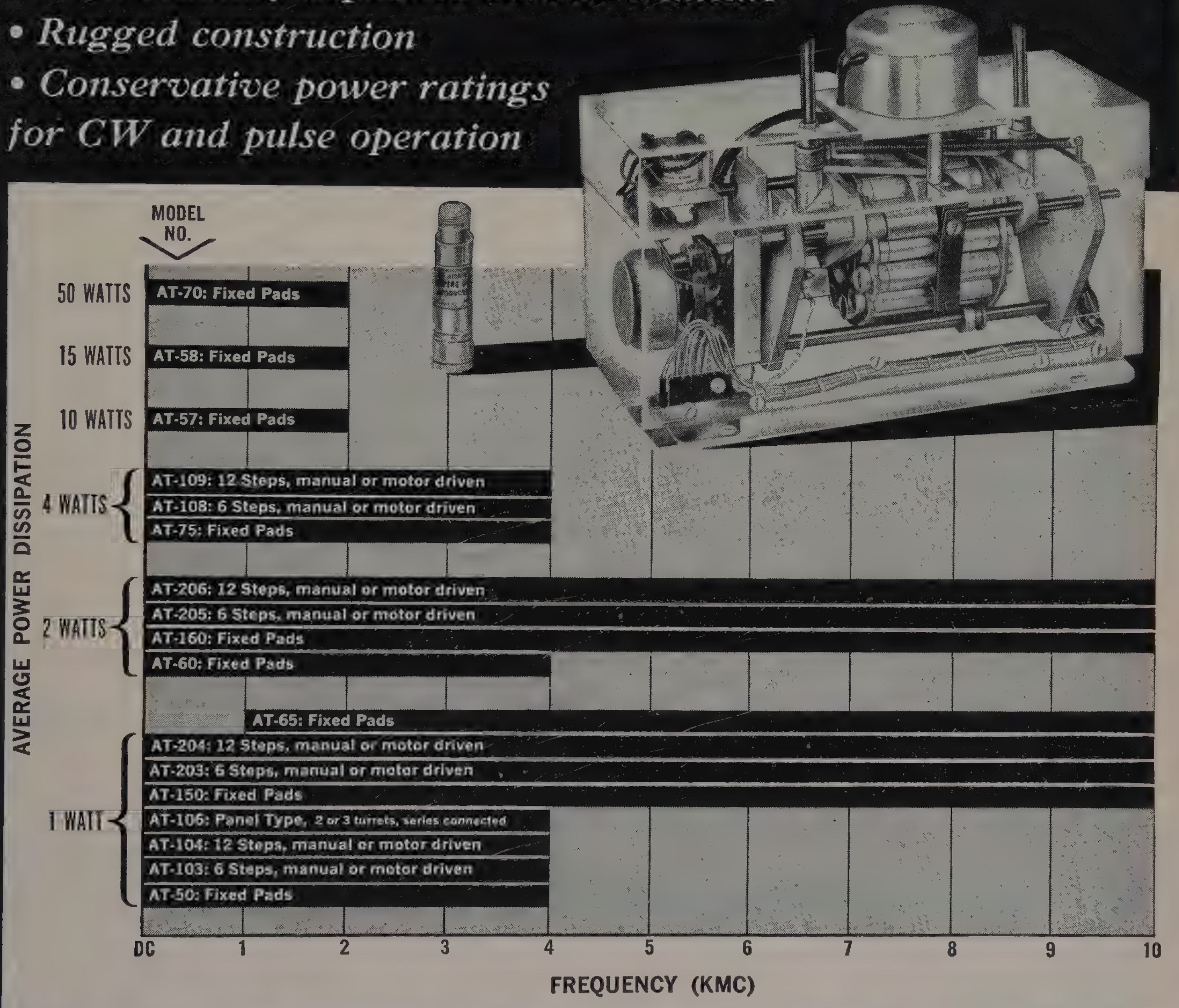
The contracts were awarded by AVCO Corporation, Electronics and Ordnance Division, Cincinnati, Ohio, and by the United States Air Force Aeronautical Systems Division (Wright Patterson Air Force Base), and the Dayton Air Force Depot.

The Electronics and Ordnance Division of AVCO Corporation awarded the Electron Tube and Device Division of Microwave Associates a contract of approximately $400,000 for design, development and manufacture of new microwave ferrite switching devices which incorporate special gas tubes.

*(Continued on page 58)*

FROM A SINGLE FIXED PAD to a 12-POSITION AUTOMATIC STEP ATTENUATOR... EMPIRE CAN MEET YOUR COAXIAL ATTENUATOR NEEDS... RATINGS FROM 1-50 WATTS... FOR OPERATION FROM DC TO 10 KMC

- *Low VSWR* • *Excellent accuracy* • *Optimum reliability*
- *High stability deposited carbon elements*
- *Rugged construction*
- *Conservative power ratings for CW and pulse operation*



*For further technical information, send for Catalog 6/4 to:*

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**EMPIRE DEVICES, Inc.**

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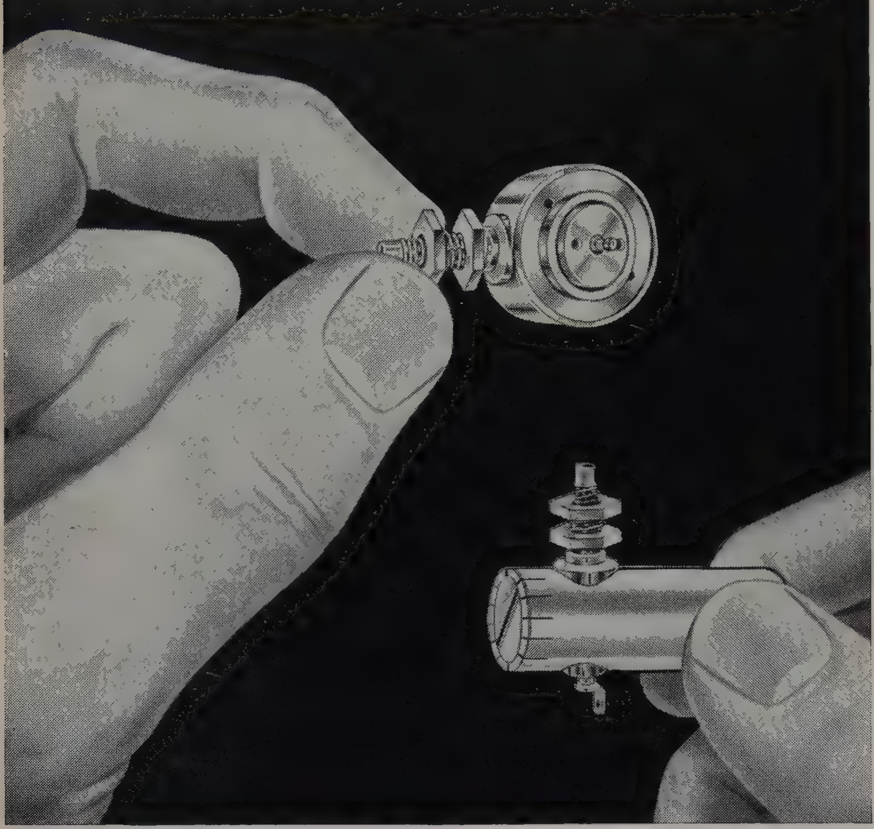
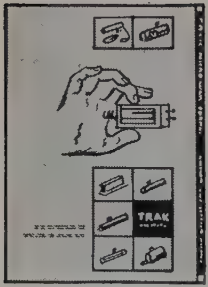
MANUFACTURERS OF: FIELD INTENSITY METERS • POWER DENSITY METERS • IMPULSE GENERATORS • COAXIAL ATTENUATORS • CRYSTAL MIXERS

**NOW...the smallest microwave oscillators we've ever made!**





TRAK MICROWAVE offers a complete line of microwave energy sources including oscillators, amplifiers and harmonic generators. Write for Catalog 61-A.
See our WESCON display — Booth 2117; ISA display — Booth 501.

Microwave projects, impossible before, are now possible with these new sub-miniature Trak microwave oscillators. Limited quantities of developmental models now available

TRAK TYPE 9180 Size: ⅜″ long by ¾″ diameter, excluding projections. Frequency: plate pulse, 4.5 KMc to 6 KMc; CW service, 4.0 to 5.5 KMc. Tuning range is limited to approximately 100 megacycles.

TRAK TYPE 9181 Size: 1½″ long by 9/16″ diameter, excluding projections. Frequency: CW service, 5.0 KMc to 6.0 KMc with tentative tuning range of 400 megacycles.

Consider the possibilities of these new oscillators, then phone us collect about projects you have in mind.

**TRAK® Microwave**

TRAK MICROWAVE CORPORATION

5006 N. Coolidge Avenue Tampa 3, Florida
PHONE: REdwood 6-6422 or REdwood 6-6407

**Specialists In Miniature Microwave Energy Sources**

Circle Reader Service Card 45

(Continued from page 56)

The Aeronautical Systems Division of the Air Force awarded Microwave Associates two contracts totalling approximately $180,000. Both involve research and development of high power, high-reliability, solid-state microwave devices.

Dayton Air Force Depot awarded Microwave Associates, Inc. a contract of approximately $125,000 for microwave semiconductor diodes.

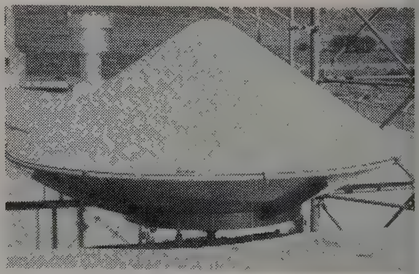
—mwj—

### LUZON MICROWAVE INTERCONNECTS PACIFIC SCATTER SYSTEM

A new Microwave Relay Communication System connecting three military communications stations on Luzon, the Philippine Islands and interconnecting into the Pacific Scatter Communications System and other systems, has been built by Page Communications Engineers Inc., Washington, D.C., for the U S. Army Signal Corps. The system is currently undergoing performance tests prior to its final acceptance by the Signal Corps.

The three stations comprising the new microwave system are Clark Air Base Communication Center, the Pacific Ionoscatter Transmitter site, and the Strategic Army Communication Network (STARCOM) HF Transmitter site. The Clark Air Base and STARCOM stations are terminal stations, with equipment at the Pacific Ionoscatter Transmitter site providing connections into the Pacific Scatter System which was installed by Page as prime contractor. The Pacific system was accepted by the Army in June, 1960.

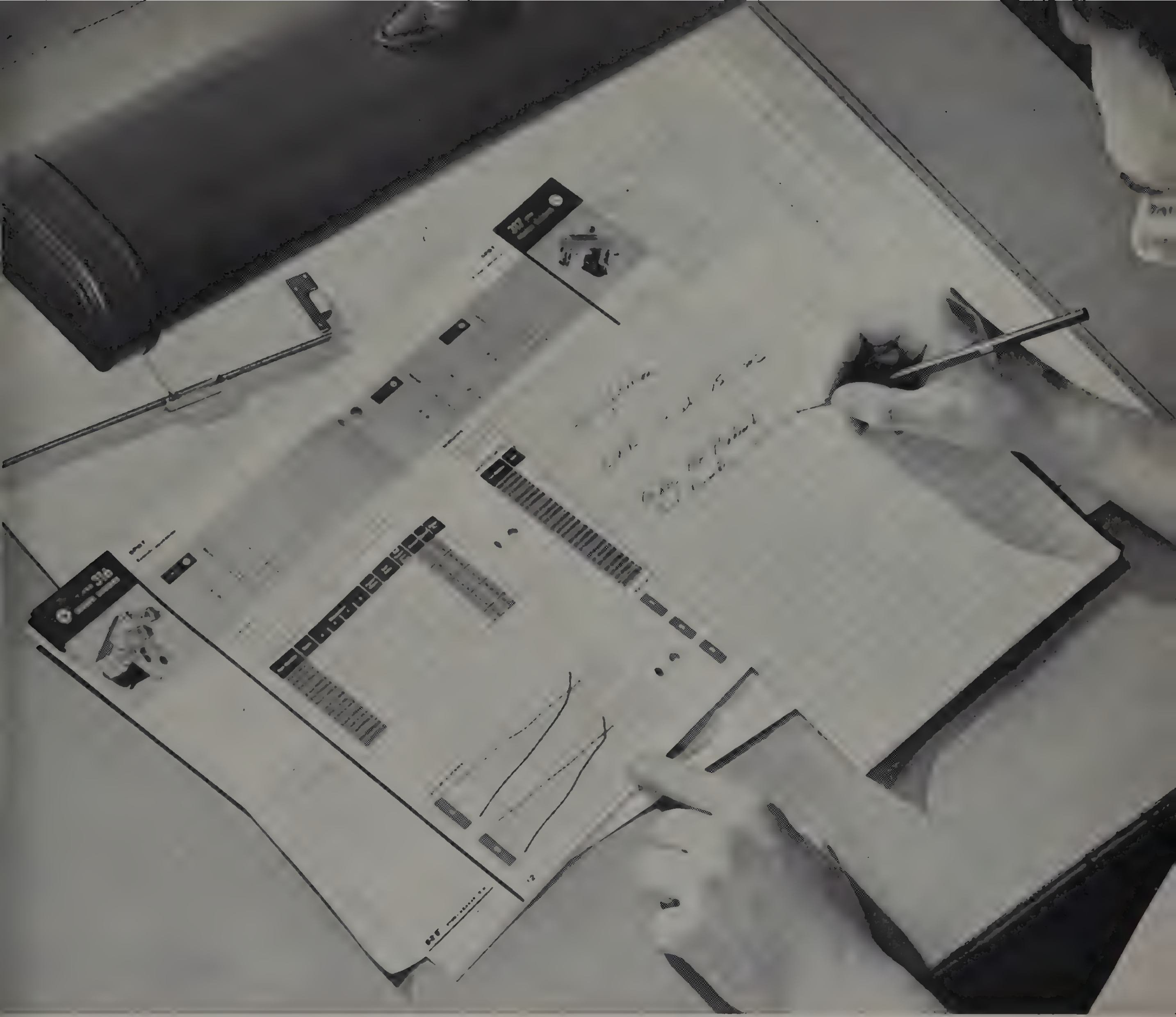
An important design-characteristic of the new radio relay system is its extremely high reliability of over 99 per cent, and a fail-safe configuration for all critical traffic handling units. It has a potential system expansion to 120 full-duplex channels.



The system presently provides 31 channels transmitting vf traffic channels from the Clark Air Base Communications Center to the STARCOM transmitter station. These channels may be used for either teleprinter or voice traffic. Three channels provide teleprinter connection with the Pacific Scatter Communication System.

—mwj—

(Continued on page 60)



# Now, you can save time and insure reliability... by specifying DK Coaxial switches in your design

It's easy. DK Coaxial switches are available in scores of shapes, sizes, and functions *from factory stock*. RF Products' new DK Coaxial switch catalog lists over 130 variations of 16 basic coax switch designs, covering a proven 90% of all known applications. All the facts and figures on the industry's most complete line of coaxial switches are at your finger tips.

You'll also find that these switches successfully combine ruggedness with the highest standards of precision: spring-leaf switching blades, gold-plated silver contacts and impedance matched connectors keep insertion loss and VSWR (1.3 @ 4,000 MCs) low, Crosstalk high (in decibels down); electro-mechanically actuated models operate and release in 8 to 20 milliseconds, depending on type and function, with a proven mechanical life of 1,000,000 cycles minimum when operated under 10 cps.

And, don't forget that RF Products, pioneers in the development of the coaxial switch, will continue to offer you design and engineering services whenever you need them. Whether you order a switch from the catalog or a switch designed to meet your exact specifications, you can be assured of the same high quality and service.

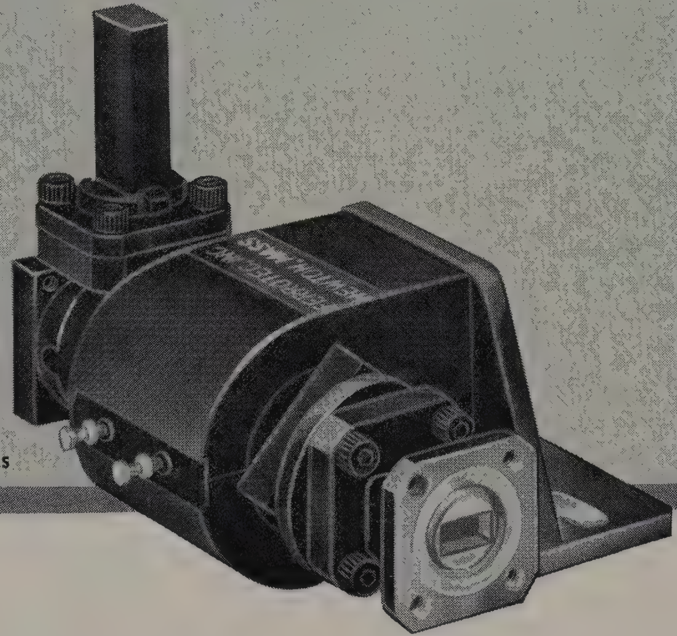
For details on our new line of standard switches, write for catalog DK 61.

**RF PRODUCTS** | DK ipc AMPHENOL

DIVISION OF AMPHENOL-BORG ELECTRONICS CORPORATION • 33 EAST FRANKLIN ST., DANBURY, CONN.

**FERROTEC . . .**

**OFFERS COMPLETE SPECTRUM COVERAGE**



FERROTEC offers the most complete line of ferrite devices to the microwave engineer — from 250 to 75,000 mc. Circulators, isolators, modulators, attenuators, and switches are available to meet the most stringent specification. You are invited to inquire about FERROTEC's high power devices available throughout the spectrum

A new miniature isolator (Model R-343L) — typical of FERROTEC's millimeter capability — is available for use at 8 mm wavelengths. This completely shielded isolator provides 20db isolation for 1db loss over a 6% band, in a 1 1/32" length, 1" dia, and a 2 oz weight.

Millimeter ferrite switches are available to cover various bands up to 75 Kmc. The 8 millimeter switch pictured above is capable of switching times of less than 1 μsec. Tabulated below is a partial listing of standard millimeter components.

| MODEL | TYPE | $f_0$ (KMC) | BANDWIDTH |
|---|---|---|---|
| R-185L | Circulator | 24 | 8% |
| R-300LS | Circulator Switch | 35 | 6% |
| R-222LS | Circulator Switch | 33 | 3% |
| R-343L | Isolator | 35 | 6% |
| T-153L | Junction Circulator | 70 | 3% |
| R-227LS | Circulator Switch | 70 | 5% |

For further information on standard units and modifications to meet specific requirements call DEcatur 2-7600 or write:

**FERROTEC INC.**

217 CALIFORNIA STREET • NEWTON 58, MASSACHUSETTS

## Industry News

(Continued from page 58)

### ZITELLI WINS SEVENTH REGION IRE AWARD

The 1961 Seventh Region IRE Electronic Achievement Award has been conferred upon Dr. Louis T. Zitelli of Varian Associates for development of the VA-849 klystron amplifier.

Citing the tube as "a major breakthrough in the achievement of high power in the microwave range," the award committee said the tube delivered the highest known CW power at X-band.

Technical literature describes the tube as delivering 20 kW CW at 7.125 to 8.500 Gc. Laboratory experiments on the same tube, slightly modified, have resulted in CW power output as high as 51.5 kW.

C. W. Carnahan, director of the Seventh Region IRE, said the award was "a fitting recognition for a truly remarkable achievement."

He pointed out that the December 1960 RCA Review carried a paper by Dr. L. S. Nergaard outlining current state-of-the-art in microwave power generation. A power-frequency chart accompanying the paper shows the highest CW power attained was 4 kW at 8 - 9 Gc. Nergaard said a major breakthrough may be required to achieve order-of-magnitude improvements.

*—mwj—*

### 1962 PGMTT SYMPOSIUM PAPERS CALLED FOR

The 1962 PGMTT National Symposium will be held on May 22-24, at the Boulder Laboratories of the National Bureau of Standards in Boulder, Colo.

A call for papers concerned with research, development, and applications in all areas of the microwave field has been issued. The Technical Program Committee for the Symposium will be particularly interested in original, creative papers dealing with topics of relatively wide and current interest.

Prospective authors will submit both 50-100 word abstracts and 500-1000 word summaries accompanied by up to eight figures, suitable for reproduction in a Symposium Digest, to be distributed to all registrants.

This material should be sent to:

R. W. Beatty, Chairman
Technical Program Committee
1962 PGMTT National Symposium
National Bureau of Standards
Boulder, Colorado

Deadline for receipt of the above material is December 18, 1961. Notifications of acceptance or rejection will be sent out by January 15, 1962. Revisions of summaries of accepted papers for the Digest will be accepted until February 15, 1962.

*—mwj—*

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# COMPACT, RELIABLE, RUGGED

EG&G

# CERAMIC-METAL

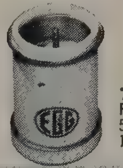
## HYDROGEN THYRATRONS—HYDROGEN DIODES—TRIGGERED SPARK GAPS

### THYRATRONS

These miniaturized hydrogen thyratrons were developed for compact modulator design for missile, airborne, and ground-based applications where size and weight are major considerations. Ruggedly built, they will withstand severe shock, vibration and high temperatures. Write for Data Sheet #040.

**7621/HY-2**
Functionally replaces 1258, 3C45 and most 4C35 glass tubes

**7620/HY-1**
Functionally replaces 4C35, 5C22 and most 5949 glass tubes



**7322/1802**
Functionally replaces 5949, 5948 and most 1257 glass tubes

**THYRATRON RATING CHART**

| MODEL | $e_{py}$ v. | $i_b$ a | $I_b$ mAdc | $I_p$ Aac | $E_f$ Vac ±7.5% | $I_f$ Aac—max. $E_f$=6.3v | $E_{res}$ Vac ±7.5% | $I_{res}$ Aac—max. $E_{res}$=6.3v | $P_b$ | Cathode & Reservoir Warm-Up Time | Dimensions Max. Height-inches | Dimensions Max. Dia.-inches | Wt. lbs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7621/HY-2 | 8,000 | 100 | 0.1 | 2.0 | 6.3 | 3.5 | * | * | 2.7 x 10⁹ | 0.5 min. | 2½″ | 1⅕″ | 0.13 |
| 7620/HY-1 | 20,000 | 500 | 0.5 | 8.0 | 6.3 | 7.5 | 6.3 | 4 | 10 x 10⁹ | 5 min. | 4⅝″ | 2⁵⁄₁₆″ | 0.82 |
| 7322/1802 | 25,000 | 1,500 | 1.5 | 47.5 | 6.3 | 16 | 6.3 | 6 | 20 x 10⁹ | 10 min. | 5¾″ | 3⅝″ | 2.07 |

*Hydrogen reservoir connected internally across heater-cathode.
Ambient Temperature Limits —65°C to +125°C, 400°C envelope maximum.

### DIODES

**HR-2**

**HR-1**

**HR-3**

High power, high voltage, hydrogen filled diodes designed for use as grid controlled rectifiers, hold-off diodes, inverse clippers and backswing clippers. In spite of their small size and light weight, they are of rugged construction and will withstand severe shock, vibration and high temperatures. Write for Data Sheet #050.

**DIODE RATING CHART**

| Type | Clipper Diode Ratings $e_{px}$ kv | Clipper Diode Ratings $i_b$ a | Clipper Diode Ratings $I_b$ Adc | Clipper Diode Ratings $I_p$ Aac | Rectifier Ratings $e_{px}$ kv | Rectifier Ratings $i_b$ a | Rectifier Ratings $I_b$ Adc | Heater $E_f$ Vac | Heater $I_f$ Iac max. | Heater $E_{res}$ Vac | Heater $I_{res}$ Iac max. | Cathode & Reservoir Warm-up Time minutes | Dimensions Max. Height-inches | Dimensions Max. Dia.-inches | Wt. lbs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR-2 | 8.0 | 9.0 | .100 | 2.0 | 8.0 | 1.5 | 0.25 | 6.3 | 3.2 | * | * | 0.5 | 2½ | 1⅕ | 0.13 |
| HR-1 | 25.0 | 250 | .125 | 4.0 | 20.0 | 9.0 | 1.5 | 5.0 | 9.5 | 5.0 | 3.5 | 5 | 4⅝ | 2⁵⁄₁₆ | 0.95 |
| HR-3 | 25.0 | 500 | .500 | 16.0 | 25.0 | 30.0 | 5.0 | 6.3 | 13.0 | 6.3 | 4.0 | 10 | 5¾ | 3⅜ | 2.07 |

*Hydrogen reservoir connected internally across cathode-heater.
Ambient Temperature Limits —65°C to +125°C ambient, 400°C envelope maximum.

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Voltage holdoff — 25kv.
Peak current — in excess of 10,000 amperes
Trigger voltage — 7 kv. min.
Electrode to electrode cut-off voltage — 6 kv. min.
Delay time — 0.5 microseconds.
Size: 3½″ dia. x 2½″. Wt. .73 lb.

**GLASS-METAL MODEL GP-11**
Voltage holdoff — 3.5 kv.
Peak current — in excess of 1100 amperes.
Trigger voltage — 7.5 kv. min.
Electrode to electrode cut-off voltage — 1.8 kv. min.
Delay time — 0.35 microseconds.
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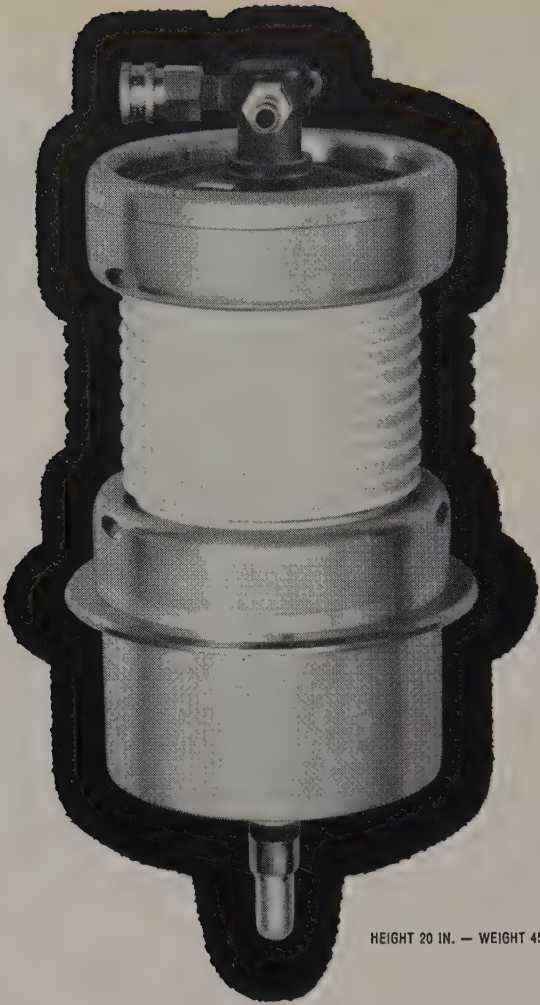

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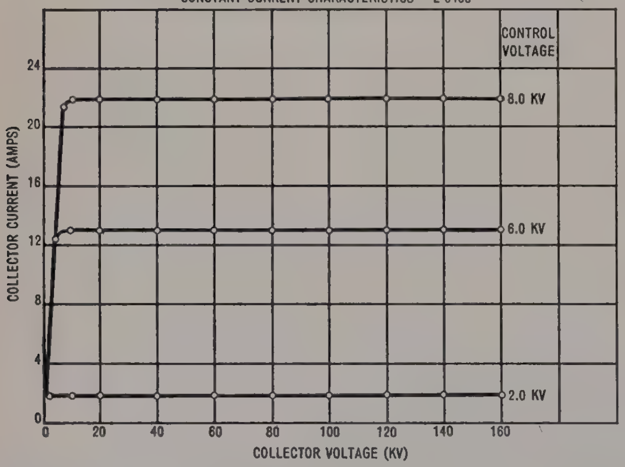

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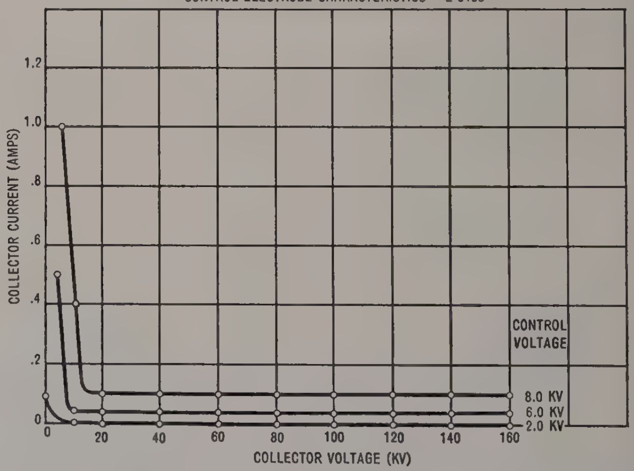

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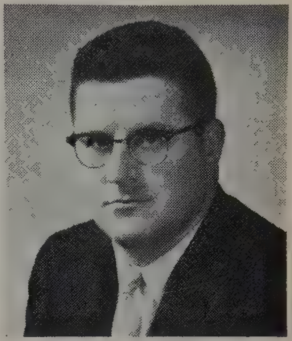
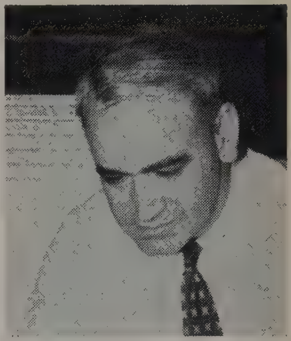


**WILLIAM B. ADAMS**, engineer, Advance Projects Development Section, General Electric Company, Heavy Military Electronics Department, Syracuse, New York, received his Bachelor of Electrical Engineering degree from Virginia Military Institute in 1946 and his Bachelor of Arts degree from Balliol College, Oxford University (England) in 1949.

Since 1959, Mr. Adams has worked on antenna and microwave developments and associated systems. Recent projects include track radar and interferometer boresighting, noise analysis and propagation effects in self-focusing antennas.

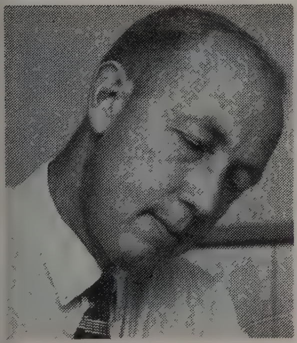
He is an associate member of the Institute of Radio Engineers, and the American Institute of Electrical Engineers.



**C. LOUIS CUCCIA** received a BS degree in Electrical Engineering in 1941, and an MS degree in 1942, both from the University of Michigan. He joined the technical staff of the RCA Laboratories at Princeton, N.J. in 1942, and worked on microwave-tube research and development until 1954.

From 1954 to 1957, he worked on special assignments in the color television activity of the laboratories, and in 1957 joined the Microwave Design Activity of the RCA Electron Tube Division in Harrison, N.J., as Engineering Leader in charge of traveling-wave tube and backward-wave oscillator design and development.

Since January 1959 he has been responsible for the product development of solid-state microwave amplifier, and since January 1960 has been manager of RCA's West Coast Microwave Electronics Laboratory.



**R. S. ELLIOTT** received a bachelors degree in English Literature at Columbia, then transferred to engineering and earned a BS in electrical engineering in 1943. For the next three years he worked on the proximity fuse, radar, and the early Bumblebee missile at the Applied Physics Laboratory.

After receiving his PhD from the University of Illinois in 1952, Mr. Elliott served a year of active duty in the Navy and was associated with a missile program undertaken by the Naval Ordnance Laboratory. Three years of employment at Hughes followed.

In 1956 Mr. Elliott left Hughes, where he had been engaged principally in research on surface wave antennas, and participated in the formation of Rantec Corporation, serving as its first Vice President and Technical Director. He is now a professor of engineering at UCLA.

Mr. Elliott is a member of Sigma Xi, Tau Beta Pi, and a Fellow of the IRE.

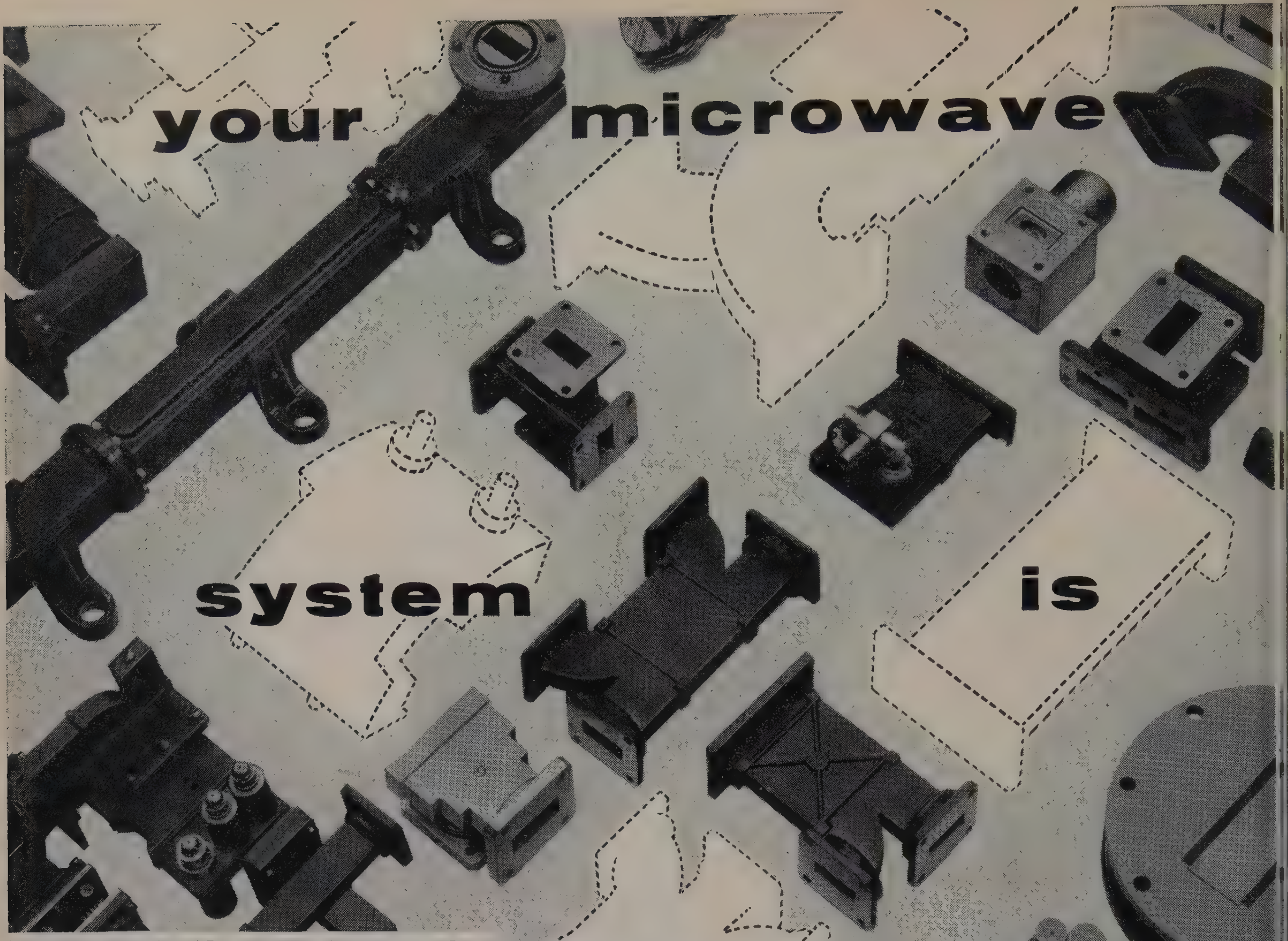
**PAUL W. HOWELLS**, manager, Advance Signal Processing Subsection, Advance Projects Development Section, General Electric Company, Heavy Military Electronics Department, Syracuse, New York, received his Bachelor of Science degree in Electrical Engineering from Syracuse University in 1942 and his Masters degree in Electrical Engineering from the University of Maine in 1949.

Since 1956, Mr. Howells has been engaged in advanced development and analytical studies of signal processing, coded signals, matched filters, and velocity scanning. His many achievements in this area include development of a Velocity Indicating Coherent Indicator (VICI) and an Automatic Cascaded AJ Receiver System, as well as invention of IF single and multiple Side-Lobe Cancellers and a Polarization canceller. He also has worked as a consultant on electronically scanned array waveform coding, and scanning and matched filter studies.

Last year Mr. Howells was elected to the rank of Fellow in the Institute of Radio Engineers for his "outstanding contributions to color television" while engaged in systems development work at the Company's Electronics Laboratory from 1950-56.

Mr. Howells also is a member of the Research Society of America, Sigma Xi, Tau Beta Pi, Pi Mu Epsilon, and has served on several NTSC, RETMA and IRE committees.

*(Continued on page 65)*



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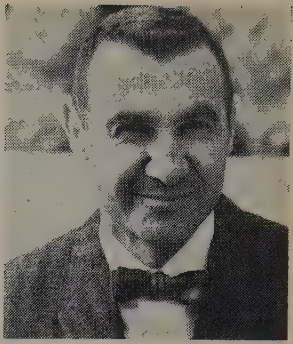


**IRVING MALTZER,** section head of the Klystron Development Department, joined Varian in 1951. He received his BS in electrical engineering in 1949 and his MS in 1951 from the University of California.

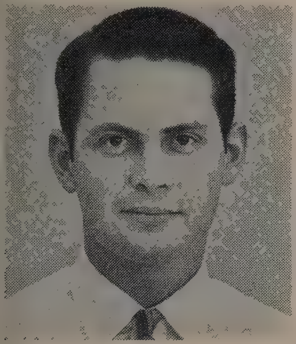
From 1949 to 1951 he was a research engineer working on electron tube development at the University of California Microwave Laboratory. While at Varian, he has been involved in projects for the development of multi-cavity pulsed klystron amplifiers and klystron frequency multipliers.

He is a member of IRE, Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

**BRUCE R. MAYO,** engineer in the Advance Projects Development Section of the General Electric Company's Heavy Military Electronics Department, Syracuse, New York, joined General Electric in 1951. He is currently engaged in research on new techniques for controlling radar antenna patterns, including the use of broadband signals. Prior to this, he was project engineer on the design of naval radar systems for the Company's Marine Radar Engineering Unit, and worked for three years at the Company's Electronics Laboratory on the development of microwave power sources and other advanced radar components. He also has done work on crystal controlled microwave power sources, cavities, and waveguide filters.

A U. S. Army Signal Corps officer for two years during World War II, Mr. Mayo holds a Master of Science and a Bachelor of Electrical Engineering degree, both from North Carolina State College. He was awarded a PhD degree in Electrical Engineering from Syracuse University in 1960. His thesis was entitled, "A Critical Analysis of Space — Frequency Equivalence in Antenna Design".

A member of the Institute of Radio Engineers since 1954, Mr. Mayo presented an award-winning paper at the IRE National Convention on Military Electronics in Washington, D.C. last year.



**EARL MC CUNE** received a BS in electrical engineering at the University of California in 1956. From 1956 to 1958 he worked part time at Varian Associates while he studied at Stanford University under the Honors Cooperative Program. In 1958 he received an MS degree in electrical engineering from Stanford.

From the time he joined Varian Associates he has worked in the Tube Development Department on the design, test and evaluation of high power X-band cw klystron amplifiers such as the VA-823 and the VA-849. In addition he has worked for two years on the design and development of a tube specifically designed for depressed collector operation.

He is a member of the IRE, Eta Kappa Nu, and Sigma Xi.

**HERBERT J. WOLKSTEIN** received a BS degree in Electrical Engineering from Newark College of Engineering and is presently working toward an MS degree in the same field. Before joining RCA, he was employed at the Research Laboratories of National Union Electric Corporation as Project Engineer on the design of special-purpose beam-deflection and computer tubes.

He joined the Microwave Tube Engineering activity of the RCA Electron Tube Division in Harrison, N.J., in 1955, and has since been engaged in the development of traveling-wave tubes. He is presently Acting Manager of the Microwave Design and Development Group.

Mr. Wolkstein is a member of the Institute of Radio Engineers and the author of several papers on traveling-wave tubes.

**LOUIS T. ZITELLI** is manager of the Klystron Development Department at Varian Associates. He majored in mathematics at San Jose State College until June, 1943, when he went on active duty with the U. S. Navy.

Zitelli attended midshipman school and pre-radar and radar training courses at Harvard University and Massachusetts Institute of Technology, later serving as an electronics officer both ashore and aboard ships. Following his discharge, he enrolled at Stanford University, where he received his MS in 1946, his EE in 1948 and his PhD in 1950. While at Stanford he was employed as part-time research assistant on projects relating to non-linear mechanics, network analyzers, reflex klystrons, traveling-wave tubes and velocity modulated electron beams.

He is a member of IRE and Sigma Xi.

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# THE TENSOR PERMITTIVITY OF A WEAKLY-IONIZED PLASMA

**R. S. ELLIOTT**
PROFESSOR OF ENGINEERING
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## I. Introduction

In an earlier series of papers[1] in *the microwave journal,* Dr. Whitmer gave a brief derivation of the complex dielectric property of an ionized medium and then discussed the considerable influence this property can exert on an electromagnetic wave passing through the medium. The present paper differs in emphasis in that the derivation of the tensor permittivity is undertaken in greater detail and only the principal cases of interaction are discussed, and then only briefly.

Let us begin by gaining an appreciation of how many molecules per cubic centimeter there are in air at various altitudes above the earth's surface. The first three columns of Table I were taken from averaged experimental data contained in "The ARDC Model Atmosphere 1956" and show the relations among height in feet, average temperature in degrees Kelvin, and average pressure in millimeters of mercury.

Air approximates an ideal gas quite well, even at sea level, and especially in the altitude range given in Table I. Hence one can write as the equation of state[2]

$$p = nkT \qquad (1)$$

in which p is the pressure, n is the volume density of molecules, k is Boltzmann's constant, and T is the absolute temperature. Forming ratios,

$$\frac{n}{n_o} = \frac{p}{p_o}\frac{T_o}{T} \qquad (2)$$

Let n be the molecule density at an arbitrary elevation and $n_o$ the value at sea level. From a knowledge of Avo-

TABLE I

AIR CONSTANTS VERSUS ALTITUDE

| HEIGHT IN FEET | TEMP. K | PRESSURE MM HG. | n MOLECULES/CC. | $\nu$ ELECTRON-MOLECULE COLLISIONS/SEC. |
|---|---|---|---|---|
| 150,000 | 278 | 1.1 | $3.8 \times 10^{16}$ | $265 \times 10^{6}$ |
| 200,000 | 253 | 0.17 | $6.5 \times 10^{15}$ | $43 \times 10^{6}$ |
| 250,000 | 197 | $1.8 \times 10^{-2}$ | $8.9 \times 10^{14}$ | $5.2 \times 10^{6}$ |
| 300,000 | 197 | $1.3 \times 10^{-3}$ | $6.4 \times 10^{13}$ | $370 \times 10^{3}$ |
| 350,000 | 220 | $1.4 \times 10^{-4}$ | $6.2 \times 10^{12}$ | $38 \times 10^{3}$ |
| 400,000 | 257 | $2.2 \times 10^{-5}$ | $8.3 \times 10^{11}$ | $5.3 \times 10^{3}$ |
| 500,000 | 458 | $1.8 \times 10^{-6}$ | $3.8 \times 10^{10}$ | 340 |
| 600,000 | 673 | $4.1 \times 10^{-7}$ | $5.9 \times 10^{9}$ | 63 |
| 800,000 | 810 | $5.7 \times 10^{-8}$ | $6.8 \times 10^{8}$ | 8 |
| 1,000,000 | 950 | $1.3 \times 10^{-8}$ | $1.3 \times 10^{8}$ | 1.7 |
| 1,200,000 | 1090 | $4.2 \times 10^{-9}$ | $3.7 \times 10^{7}$ | 0.51 |
| 1,400,000 | 1230 | $1.7 \times 10^{-9}$ | $1.3 \times 10^{7}$ | 0.19 |
| 1,600,000 | 1365 | $7.4 \times 10^{-10}$ | $5.3 \times 10^{6}$ | 0.08 |
| 1,800,000 | 1500 | $3.7 \times 10^{-10}$ | $2.4 \times 10^{6}$ | 0.04 |

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gadro's number and the pressure, temperature, and volume of one mole of air at standard conditions, one can deduce that $n_o=2.7 \times 10^{19}$ molecules/cc. With this information, (2) can be rewritten as

$$n=9.7 \times 10^{18} \frac{p}{T} \qquad (3)$$

in which p is in millimeters of mercury and T is in degrees Kelvin. Equation (3) was used to construct the fourth column of Table I.

It is apparent from an inspection of the fourth column that, even at the highest altitudes considered in Table I, there is a sufficient particle density to justify the use of statistical methods. Thus, the following discussion of mean free path and collision frequency is applicable.

Imagine that the air is slightly ionized‡ (one per cent or less) by extra-terrestrial energy sources creating the normal ionosphere, or by a high speed vehicle which heats up the air as it passes through it. Under normal circumstances, the vast majority of resulting ions are singly charged. The free electron density is then one per cent or less of the values listed in the fourth column of Table I. These free electrons will collide with neutral molecules, with ions, and with other electrons. The preponderance of collisions will be with neutral molecules, and these are the only collisions which shall be considered. Since oxygen and nitrogen molecules average above 50,000 times the mass of an electron, if we invoke the equipartition principle, it follows that the free electrons have about 230 times the average speed of the molecules*. Because of this, one can assume, for the purpose of computing collisions, that the molecules are standing still, with the free electrons moving through the molecular lattice in a zig-zag path composed of straight line segments between collisions.

If D is the collision diameter of the molecules and one imagines a cylindrical tube of diameter D erected around the electron path as axis, then the electron will collide with all molecules whose centers lie within the tube. In a length L of the path, the tube has a volume $\frac{\pi}{4} D^2L$ and contains $\frac{\pi}{4} nD^2L$ molecules. The mean free path λ is the average distance between collisions. Thus,

$$\lambda=\frac{4}{\pi n D^2} \qquad (4)$$

If $\bar{v}$ is the average speed of the free electrons, the frequency of collision is

$$\nu=\frac{\bar{v}}{\lambda} = \frac{\pi}{4} D^2 n\bar{v} \qquad (5)$$

Experimental data in the range of interest[3] show the mean free path to be a slowly varying function of temperature at constant pressure. At a pressure of 1 mm., a useable average value is $\lambda=4 \times 10^{-2}$ cm. Combining equations (4) and (2), this translates into a mean free path at standard conditions of

$$\lambda_o=5.7 \times 10^{-5} \text{ cm.} \qquad (6)$$

The electron gas is constrained to obey Maxwell-Boltzmann statistics through its mixture with a dominant concentration of neutral molecules. Therefore, it follows[4] that

$$\bar{v}=\sqrt{\frac{8kT}{\pi m}} \qquad (7)$$

and $v_o \cong 10^5$ meters/second! At standard conditions $\nu_o \cong 1.8 \times 10^{11}$ collisions/sec. and at any arbitrary elevation

$$\nu=4 \times 10^9 \frac{p}{\sqrt{T}} \quad \text{collisions/sec.} \qquad (8)$$

Equation (8) has been used in the computation of the fifth column of Table I. These data will assume important meaning in our later discussions.

Without expressly mentioning it, we have already made use of the *mean time* between collisions, $\lambda/\bar{v}$, to define collision frequency. We shall also need the distribution function of times between collisions of free electrons with neutral molecules as the electrons move randomly among the molecules. To this end, consider a large number of electrons $N_g$ which are just about to have a collision at the present time t. Let $N(t_1+dt_1)$ be the number of these which haven't had a collision since the earlier time $t_1+dt_1$. At a still earlier time $t_1$, this number has been reduced to $N(t_1)$. Then

$$dN=N(t_1+dt_1)-N(t_1) \qquad (9)$$

is the number of electrons within the group $N_g$ which suffered a collision during the time interval $dt_1$.

It is reasonable to assume that dN is proportional to N and to $dt_1$. Thus

$$dN=CNdt_1 \qquad (10)$$

in which C is a proportionality constant. Integrating,

$$N=N_g e^{-C(t-t_1)} \qquad (11)$$

and thus

$$dN=CN_g e^{-C(t-t_1)} dt_1 \qquad (12)$$

dN is also the number of electrons within the group $N_g$ which had their last collision $(t-t_1)$ units of time ago. Considering *all* the electrons $N_g$, the mean time between collisions, τ, is given by

$$\tau=\frac{1}{\nu} = \frac{1}{N_g}\int_0^{N_g} (t-t_1)dN= \int_{-\infty}^{t} (t-t_1)Ce^{-C(t-t_1)} dt_1 \qquad (13)$$

and thus $C=\nu$. Therefore,

$$dN=N_g \nu e^{-\nu(t-t_1)} dt_1 \qquad (14)$$

---

‡ *Since the resulting partially ionized air is electrically neutral, it is referred to as a plasma.*

* *This assumes that the free electron temperature is the same as the air temperature. In many cases, it is higher than the air temperature, thus raising the ratio above 230.*

is the distribution function of times between collisions. It shall prove useful, shortly, in the derivation of the complex tensor permittivity of a plasma medium.

## II. Analysis

We now turn to a consideration of the interaction of an electromagnetic wave with a plasma medium of the type just discussed. In the atmosphere this would be ionized air pervaded by the earth's magnetic field or perhaps subjected to localized dc fields by the passage of a high speed vehicle. In the laboratory, the plasma medium might be any suitable gas, more often than not excited by a dc electric field, perhaps in the presence of a dc magnetic field. To cover all these cases we consider a plasma region in which a uniform dc magnetic field of strength $\vec{B}_o$ exists. No loss of generality results from taking the z axis in the direction of $\vec{B}_o$. A uniform dc electric field

$$\vec{E}_o = \vec{u}_x E_{ox} + \vec{u}_y E_{oy} + \vec{u}_z E_{oz} \tag{15}$$

is also assumed to exist in the region. A plane electromagnetic wave traversing this region can be characterized by

$$\vec{E}_1 = (\vec{u}_x E_{1x} + \vec{u}_y E_{1y} + \vec{u}_z E_{1z}) e^{j\omega t - \gamma_x x - \gamma_y y - \gamma_z z} \tag{16}$$

in which $E_{1x}$, $E_{1y}$, $E_{1z}$ are complex constants and $\gamma_x$, $\gamma_y$, $\gamma_z$ are components of the complex propagation constant.

In a volume V centered around the origin and small in linear dimensions compared to the wavelength of the plane wave,

$$\vec{E} = \vec{E}_o + \vec{E}_1 = \vec{u}_x (E_{ox} + E_{1x} e^{j\omega t}) + \vec{u}_y (E_{oy} + E_{1y} e^{j\omega t}) + \vec{u}_z (E_{oz} + E_{1z} e^{j\omega t}) = \vec{u}_x E_x + \vec{u}_y E_y + \vec{u}_z E_z \tag{17}$$

is the total electric field. The force on a free electron in V, between collisions, is given by

$$\vec{F} = -e(\vec{E} + \vec{v} \times \vec{B}) \tag{18}$$

in which e is the magnitude of the charge on the electron. In (18), $\vec{B}$ is the sum of the magnetic field of the plane wave and the dc magnetic field $\vec{u}_z B_o$. Since $\vec{v}$, the velocity of the electron, is small compared to the velocity of light for field strengths of interest the contribution due to the magnetic field of the plane wave is negligible. Thus (18), coupled with Newton's force law, gives

$$\begin{aligned} m\dot{v}_x &= -e(E_x + v_y B_o) \\ m\dot{v}_y &= -e(E_y - v_x B_o) \\ m\dot{v}_z &= -eE_z \end{aligned} \tag{19}$$

Integrating the third equation of (19) gives

$$v_z = -\frac{eE_{1z}}{j\omega m} e^{j\omega t} - \frac{eE_{oz}}{m} t + v_{oz} \tag{20}$$

in which $v_{oz}$ is a constant of integration. Differentiating the second equation of (19) and eliminating $\dot{v}_x$ by means of the first equation gives

$$\ddot{v}_y + \omega_b{}^2 v_y = -\omega_b{}^2 \frac{E_x}{B_o} - j\omega\omega_b \frac{E_y}{B_o} e^{j\omega t} \tag{21}$$

in which $\omega_b = \dfrac{eB_o}{m}$ is called the cyclotron frequency. In Table II the values of $\omega_b$ can be found corresponding to a range of values of $B_o$.

Equation (21) has the solution

$$v_y = A_1 e^{j\omega_b t} + A_2 e^{-j\omega_b t} + \frac{\omega_b{}^2}{\omega^2 - \omega_b{}^2} \frac{E_{1x}}{B_o} e^{j\omega t} + \frac{j\omega\omega_b}{\omega^2 - \omega_b{}^2} \frac{E_{1y}}{B_o} e^{j\omega t} - \frac{E_{ox}}{B_o} \tag{22}$$

in which $A_1$ and $A_2$ are constants. From (19) it follows that

$$v_x = jA_1 e^{j\omega_b t} - jA_2 e^{-j\omega_b t} + \frac{j\omega\omega_b}{\omega^2 - \omega_b{}^2} \frac{E_{1x}}{B_o} e^{i\omega t} - \frac{\omega_b{}^2}{\omega^2 - \omega_b{}^2} \frac{E_{1y}}{B_o} e^{i\omega t} + \frac{E_{oy}}{B_o} \tag{23}$$

It is convenient for visualization purposes to write

$$\vec{v} = \vec{v}_{\omega_b} + \vec{v}_{\omega} \tag{24}$$

in which

$$\vec{v}_{\omega_b} = \vec{u}_x \left[ v_{oy} \cos\left( \omega_b t + \frac{\pi}{2} \right) + v_{ox} \sin\left( \omega_b t + \frac{\pi}{2} \right) \right] + \vec{u}_y [v_{oy} \cos \omega_b t + v_{ox} \sin \omega_b t] + \vec{u}_x \frac{E_{oy}}{B_o} - \vec{u}_y \frac{E_{ox}}{B_o} - \vec{u}_z \left( \frac{E_{oz}}{B_o} \omega_b t - v_{oz} \right) \tag{25}$$

and

$$\vec{v}_{\omega}=\frac{\omega_b}{B_o}\frac{e^{j\omega t}}{\omega^2-\omega_b^2}\left[\vec{u}_x(j\omega E_{1x}-\omega_b E_{1y})+\vec{u}_y(\omega_b E_{1x}+j\omega E_{1y})-\vec{u}_z\frac{\omega^2-\omega_b^2}{j\omega}E_{1z}\right] \qquad (26)$$

Equation (25) has been obtained via the substitutions* $v_{oy}=A_1+A_2$ and $v_{ox}=j(A_1-A_2)$. (25) is recognized as helical motion along the z axis with a pitch which changes linearly with time, plus a lateral drift. (26) is elliptical motion in a tilted plane.

Thus, the general motion can be described as follows: The electron travels in an elliptical orbit the shape, size, and tilt of which are determined by $B_o$ and the plane wave. The angular frequency in this elliptical orbit is $\omega$. The *center* of the ellipse glides along a helical path. The helical path has an axis which is parallel to $B_o$, a pitch which changes linearly with time, and a constant lateral drift. The center of the ellipse moves along the turns of the helix at the angular frequency $\omega_b$.

Equation (24) describes the motion of an electron in the small volume V while it is between collisions. Of course, there are many such electrons and they share the common motion $v_{\omega}$. However, the helical parts of their motions differ because they came off their last collisions with different initial velocities. We wish to find the *mean* velocity of the electrons. To accomplish this, consider a large number of electrons, $N_g$, in the volume V, at the present time t. Tracing the past history of these electrons, we single out the subgroup dN which had their last collisions in the earlier time interval between $t_1$ and $t_1+dt_1$. If the volume element V is big enough so that we can go far enough back in time to count the last collision of most of the $N_g$ electrons and still have them in V, then (24) applies to each of these electrons. For the subgroup dN, the mean value $<\vec{v}>$ of velocity at $t_1+dt_1$ is given by

$$<\vec{v}(t_1+dt_1)>=\vec{u}_x\left[j<A_1>e^{j\omega_b t_1}-j<A_2>e^{-j\omega_b t_1}\right]+\vec{u}_y\left[<A_1>e^{j\omega_b t_1}+<A_2>e^{-j\omega_b t_1}\right]+\vec{u}_x\frac{E_{oy}}{B_o}$$
$$-\vec{u}_y\frac{E_{ox}}{B_o}-\vec{u}_z\left[\frac{E_{oz}}{B_o}\omega_b t_1-<v_{oz}>\right]+\vec{v}_{\omega}(t_1) \qquad (27)$$

This is the mean velocity of all the dN electrons right after each has had a collision with a molecule. In the absence of the plane wave and the dc fields, by symmetry, this mean velocity would be zero. These external fields superimpose an ordered velocity component on the random motion, which perturbs this symmetry. However, we recall from the discussion following equation (7) that the mean *random* speed at normal temperatures is about $10^5$ meters/sec. In many practical cases, the ordered component of velocity resulting from the external fields is small compared to this mean random speed and the perturbation of symmetry is negligible. We shall assume this to be the case and write $<\vec{v}(t_1+dt_1)>=0$. Equation (27) can then be used to compute $<A_1>$, $<A_2>$, and $<v_{oz}>$. When this is done, one obtains

$$<A_1>=e^{-j\omega_b t_1}\left[\frac{E_{ox}+jE_{oy}}{2B_o}\right]-\frac{\omega_b}{2B_o}\frac{e^{j(\omega-\omega_b)t_1}}{\omega-\omega_b}\left[E_{1x}+jE_{1y}\right]$$
$$<A_2>=e^{j\omega_b t_1}\left[\frac{E_{ox}-jE_{oy}}{2B_o}\right]+\frac{\omega_b}{2B_o}\frac{e^{j(\omega+\omega_b)t_1}}{\omega+\omega_b}\left[E_{1x}-jE_{1y}\right] \qquad (28)$$
$$<v_{oz}>=\frac{E_{oz}}{B_o}\omega_b t_1+\frac{\omega_b}{j\omega}\frac{E_{1z}}{B_o}e^{j\omega t_1}$$

From this, it follows that the mean value of velocity for the subgroup dN, at the present time t, is

$$<\vec{v}(t)>=(\vec{u}_y+j\vec{u}_x)\frac{e^{j\omega_b(t-t_1)}}{2B_o}\left[E_{ox}+jE_{oy}-\frac{\omega_b}{\omega-\omega_b}e^{j\omega t_1}(E_{1x}+jE_{1y})\right]$$
$$+(\vec{u}_y-j\vec{u}_x)\frac{e^{-j\omega_b(t-t_1)}}{2B_o}\left[E_{ox}-jE_{oy}+\frac{\omega_b}{\omega+\omega_b}e^{j\omega t_1}(E_{1x}-jE_{1y})\right]$$
$$+\vec{u}_x\frac{E_{oy}}{B_o}-\vec{u}_y\frac{E_{ox}}{B_o}-\vec{u}_z\left[\frac{E_{oz}}{B_o}\omega_b(t-t_1)+\frac{j\omega_b}{\omega}\frac{E_{1z}}{B_o}e^{j\omega t_1}\right]+\vec{v}\omega(t) \qquad (29)$$

---

* *$\vec{v}_o=\vec{u}_x v_{oz}+\vec{u}_y v_{oy}+\vec{u}_z v_{oz}$ can be identified as the drift velocity when $B_o\rightarrow 0$.*

Equation (29) gives the average velocity for the subgroup of electrons which had their last collision between $t_1$ and $t_1+dt_1$. If we let $<<\vec{v}(t)>>$ represent the average velocity for *all* the subgroups, then

$$<<\vec{v}(t)>>=\frac{1}{N_g}\int_{-\infty}^{t}<\vec{v}(t)>dN(t_1) \qquad (30)$$

in which $<\vec{v}(t)>$ is given by (29) and dN is given by (14). Except for one term, the integration of (30) is very direct, and one obtains

$$<<\vec{v}(t)>>=\frac{\omega_b}{\nu^2+\omega_b^2}\left\{\vec{u}_x\left(-\nu\frac{E_{ox}}{B_o}+\omega_b\frac{E_{oy}}{B_o}\right)-\vec{u}_y\left(\omega_b\frac{E_{ox}}{B_o}+\nu\frac{E_{oy}}{B_o}\right)\right\}+\vec{u}_zF(E_{oz},B_o)$$

$$-\frac{e}{m}e^{j\omega t}\left\{\vec{u}_x\left(\frac{\nu+j\omega}{(\nu+j\omega)^2+\omega_b^2}E_{1x}-\frac{\omega_b}{(\nu+j\omega)^2+\omega_b^2}E_{1y}\right)\right.$$

$$\left.+\vec{u}_y\left(\frac{\omega_b}{(\nu+j\omega)^2+\omega_b^2}E_{1x}+\frac{\nu+j\omega}{(\nu+j\omega)^2+\omega_b^2}E_{1y}\right)+\vec{u}_z\frac{E_{1z}}{\nu+j\omega}\right\} \qquad \textbf{(31)}$$

The troublesome term is $-u_z\frac{E_{oz}}{B_o}\omega_b(t-t_1)$ of equation (29). Its integration provides an infinite contribution to the z -component of the average velocity. The reasons for this can be traced from the lower limit of integration, which requires going back indefinitely far in time. Under our assumptions those few electrons which have escaped collision that long have traveled an indefinitely large distance, and are going at an indefinitely large velocity. Any finite geometry would rule out these few electrons. Even in an idealized situation, proper regard for relativistic effects, increase in collision cross-section with high speed, etc., would remove this singularity. For the purposes of the present paper, it is not profitable to pursue this point in greater detail. We acknowledge the proper contribution of this term by including a velocity component $\vec{u}_zF(E_{oz},B_o)$ in (31) with the understanding that F is also a function of the geometry. This difficulty does not arise in any other term in the integrand of (30), since all other terms decay as we go back in time.

It is significant to note from (31) that the mean velocity of all the electrons has a dc part controlled by the dc fields alone and an ac part *which is unaffected by the dc electric field.* This result is traceable to the assumption of weak fields and has important implications in the use of plasma tubes for simulation studies. This separation of the dc and ac effects is the reason for not pursuing more deeply the nature of the term $F(E_{oz},B_o)$ in (31), for we now wish to turn our attention entirely to the ac part of (31).

In the region V, Maxwell's equations can be written for the ac fields as

$$\nabla\times\vec{E}_1=-j\omega\mu_o\vec{H}_1 \qquad (32)$$

$$\nabla\times\vec{H}_1=\vec{i}+j\omega\epsilon_o\vec{E}_1=-N_ee<<\vec{v}_1>>+j\omega\epsilon_o\vec{E}_1 \qquad (33)$$

in which $N_e$ is the electron density and $<<\vec{v}_1>>$ is the ac part of (31). If we define the plasma frequency by the relation

### TABLE II

### CYCLOTRON FREQUENCY VS. FLUX DENSITY

| $B_o$ gauss | $f_b=\frac{1}{2\pi}\frac{eB_o}{m}$ |
|---|---|
| 143 | 400 MC |
| 357 | 1000 MC |
| 1070 | 3000 MC |
| 2140 | 6000 MC |
| 3570 | 10,000 MC |
| 12,500 | 35,000 MC |

### TABLE III

### PLASMA FREQUENCY VERSUS ELECTRON DENSITY

| $N_e$ ELECTRONS/cc | PLASMA FREQUENCY |
|---|---|
| $10^8$ | 90 MC |
| $10^9$ | 285 MC |
| $10^{10}$ | 900 MC |
| $10^{11}$ | 2850 MC |
| $10^{12}$ | 9 GC |
| $10^{13}$ | 28.5 GC |
| $10^{14}$ | 90 GC |
| $10^{15}$ | 285 GC |
| $10^{16}$ | 900 GC |
| $10^{17}$ | 2850 GC |
| $10^{18}$ | 9040 GC |

$$\omega_p = \sqrt{\frac{N_e e^2}{m\epsilon_o}} \qquad (34)$$

the wave equation can be written

$$\nabla \times \nabla \times \vec{E}_1 = k_o^2 \left[ \vec{E}_1 - \frac{\omega_p^2}{j\omega} \frac{m}{e} << \vec{v}_1 >> \right] \qquad (35)$$

in which $k_o = \omega\sqrt{\mu_o \epsilon_o} = \dfrac{2\pi}{\lambda_o}$ is the free space propagation constant. The values of plasma frequency corresponding to various electron concentrations can be found in Table III.

If the appropriate part of (31) is substituted in (35), the result can be written as a tensor equation,

$$\begin{pmatrix} (\nabla \times \nabla \times E_1)_x \\ (\nabla \times \nabla \times E_1)_y \\ (\nabla \times \nabla \times E_1)_z \end{pmatrix} = k_o^2 \begin{pmatrix} \epsilon_{11} & \epsilon_{12} & 0 \\ -\epsilon_{12} & \epsilon_{11} & 0 \\ 0 & 0 & \epsilon_{33} \end{pmatrix} \begin{pmatrix} E_{1x} \\ E_{1y} \\ E_{1z} \end{pmatrix} \qquad (36)$$

with

$$\epsilon_{11} = 1 + \frac{\omega_p^2}{j\omega} \frac{\nu + j\omega}{(\nu + j\omega)^2 + \omega_b^2} \qquad (37)$$

$$\epsilon_{12} = -\frac{\omega_p^2}{j\omega} \frac{\omega_b}{(\nu + j\omega)^2 + \omega_b^2} \qquad (38)$$

$$\epsilon_{33} = 1 + \frac{\omega_p^2}{j\omega} \frac{1}{\nu + j\omega} \qquad (39)$$

Equation (36) is perhaps the most important result in the theory of the interaction between plasmas and electromagnetic waves. It reveals the tensor nature of the equivalent permittivity of the plasma. Interestingly, this tensor has the same form[5,6] as that of the permeability of an anisotropic ferrite medium and an extensive duality exists in the manner in which both media interact with electromagnetic waves.

The interplay of the four parameters $\nu$, $\omega$, $\omega_p$, and $\omega_b$ in equation (36) is best illuminated by discussing several important cases.

## IV. Propagation with $\vec{E}_1$ 11 $\vec{B}_o$

If the plasma region is homogeneous over a sufficiently large region to warrant seeking a plane wave solution, three major cases of interest arise. The first of these involves propagation in a direction perpendicular to $\vec{B}_o$ with $\vec{E}_1$ parallel to $\vec{B}_o$. We therefore seek a solution of the type

$$\vec{E}_1 = \vec{u}_z e^{j(\omega t - kx)} \qquad (40)$$

Upon inserting (40) in (36) one finds that

$$\left(\frac{k}{k_o}\right)^2 = \epsilon_{33} = 1 + \frac{\omega_p^2}{j\omega} \frac{1}{\nu + j\omega} \qquad (41)$$

Thus for this case the propagation constant does not depend on $B_o$ and the dc magnetic field might just as well not be present. Indeed, this is the solution for propagation in *any* direction in the absence of the dc magnetic field.

Recalling Table I, we note that $\nu << \omega$ for many practical applications. Ignoring $\nu$ altogether for the moment, (41) becomes

$$\left(\frac{k}{k_o}\right)^2 = 1 - \left(\frac{\omega_p}{\omega}\right)^2 \qquad (42)$$

revealing the importance of the plasma frequency. If $\omega_p < \omega$ propagation of a fast wave is possible, but if $\omega_p > \omega$, the wave is attenuated. Small values of $\nu$ change this conclusion only slightly, principally through the introduction of an attenuation when $\omega_p < \omega$. The general case of (41) is widely discussed in the literature.[7]

## V. Propagation Parallel to $\vec{B}_o$

For this case, we seek a solution of the form

$$\vec{E}_1 = \vec{u}_x A e^{j(\omega t - kz)} + \vec{u}_y B e^{j(\omega t - kz)} \qquad (43)$$

and make this substitution in (36). Two sub-cases result. If $B = jA$,

$$\left(\frac{k}{k_o}\right)^2 = \epsilon_{11} + j\epsilon_{12} \qquad (44)$$

whereas, if $B = -jA$,

$$\left(\frac{k}{k_o}\right)^2 = \epsilon_{11} - j\epsilon_{12} \qquad (45)$$

Thus right-handed and left-handed circularly polarized planes can propagate, but at *different* phase velocities. Since a linearly polarized plane wave can be thought of as equal amounts of right and left circularly polarized waves, it follows that the plane of polarization of the linearly polarized wave will rotate as it passes through the plasma medium. This is the well-known Faraday effect.

If $\nu$ can be neglected,

$$\epsilon_{11} \pm j\epsilon_{12} = 1 - \frac{\omega_p^2}{\omega(\omega \pm \omega_b)} \qquad (46)$$

and one mode is seen to change from a pass band to a stop band when $\omega_p^2 = \omega(\omega + \omega_b)$ whereas the other changes when $\omega_p^2 = \omega(\omega - \omega_b)$. This type of propagation has also been treated extensively in the literature.[8]

## VI. Propagation Perpendicular to $\vec{B}_o$, $\vec{E}_1 \perp \vec{B}_o$

In this case, the wave turns out to have a longitudinal $E_1$ component as well and we seek a solution of the type

$$\vec{E}_1 = \vec{u}_x A e^{j(\omega t - kx)} + \vec{u}_y B e^{j(\omega t - kx)} \qquad (47)$$

Upon inserting (47) in (36), one finds that

$$\frac{A}{B} = -\frac{\epsilon_{12}}{\epsilon_{11}} \text{ (usually small)} \qquad (48)$$

$$\left(\frac{k}{k_o}\right)^2 = \frac{\epsilon_{11}^2 + \epsilon_{12}^2}{\epsilon_{11}} \qquad (49)$$

$$\left(\frac{k}{k_o}\right)^2 = \frac{\left[1 - \dfrac{\omega_p^2}{\omega(\omega + \omega_b)}\right]\left[1 - \dfrac{\omega_p^2}{\omega(\omega - \omega_b)}\right]}{\left[1 - \dfrac{\omega_p^2}{\omega^2 - \omega_b^2}\right]} \quad (\nu = 0) \qquad (50)$$

We see that in this case propagation alternates between pass and stop bands with the transitions occurring when $\omega_p^2 = \omega(\omega - \omega_b), \omega_p^2 = (\omega + \omega_b)(\omega - \omega_b), \omega_p^2 = \omega(\omega + \omega_b)$. This 'triple resonance' effect can prove very useful in plasma diagnostics problems.[9]

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# A 20 KW CW X-BAND KLYSTRON AMPLIFIER

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## I. Introduction

During the past few years there has been an increasing demand for higher c-w power at microwave frequencies. C-w illuminators, space communications, long range radar, forward scatter and radio astronomy are a few of the applications where high power coherent sources are attractive. For a given average power the small size of the components, the greater resolution in addition to the high gain of reasonable size antennas, makes X-band power particularly attractive. For example, the use of X-band in conjunction with a 100-foot parabolic reflector will result in a beam width of 0.07 degrees and the main part of the power will be in a circle of less than half this. With this antenna pointed at the moon, a circle 400 miles in diameter will be illuminated. This is about twice as large as the moon's largest crater. The variation in X-band reflections across the surface of the moon can be measured and evaluated.

At an X-band power level of 20 kilowatts cw, and with an antenna of this size, the detection of reflected signals from some of the closer planets becomes practical.

The above mentioned applications are of considerable interest; however, perhaps more important than these are the implications as to what average powers can be produced at other frequencies. A recent survey article by Nergaard on power limitations of microwave transmitting tubes shows a plot of power output as a function of frequency for a number of different power tubes. Figure 1 is a copy of Nergaard's data modified to include the VA-849 as well as data obtained on a modified VA-849. If one takes the performance of the standard VA-849 and extrapolates down in frequency on a $Pf^2$=constant basis (where P is average power output and f is frequency), it is indicated that c-w powers of 1 megawatt can be generated at 1100 megacycles. Actually, it should be possible to do better than this since the r-f losses are proportionately less at the lower frequency and it is also possible to do a more effective job on cooling the most critical items in the present designs such as the drift tubes and the windows.

It is clearly indicated from the above mentioned data that the VA-849 has generated about one order of magnitude more average power than any other microwave device (on a $Pf^2$=constant basis). One experimental VA-849 tube has delivered 51.5-kw c-w power output into a match load without any harmful effects on the tube. How this was achieved is, of course, of considerable interest, and while it is not our purpose here to go into the de-

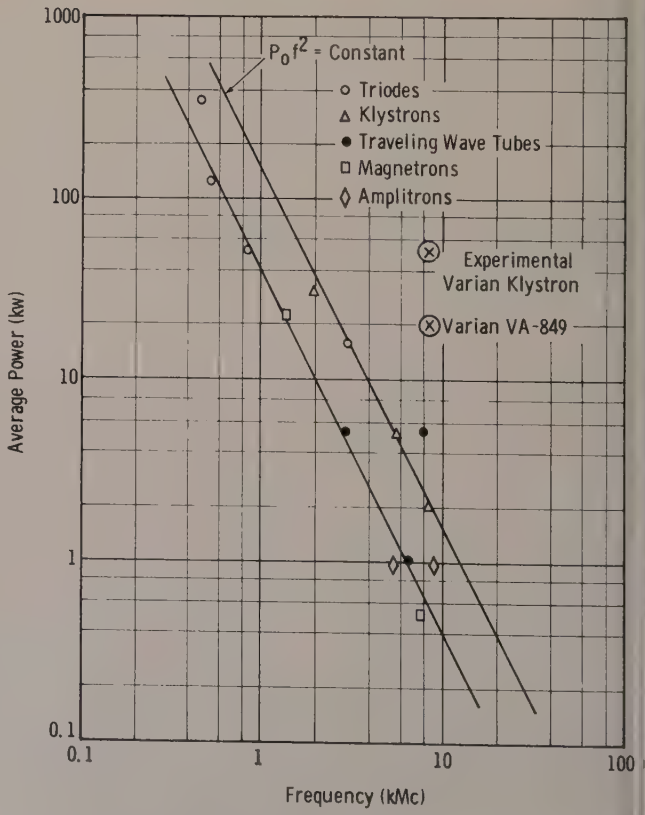

Figure 1 — Average power output as a function of frequency for microwave tubes.

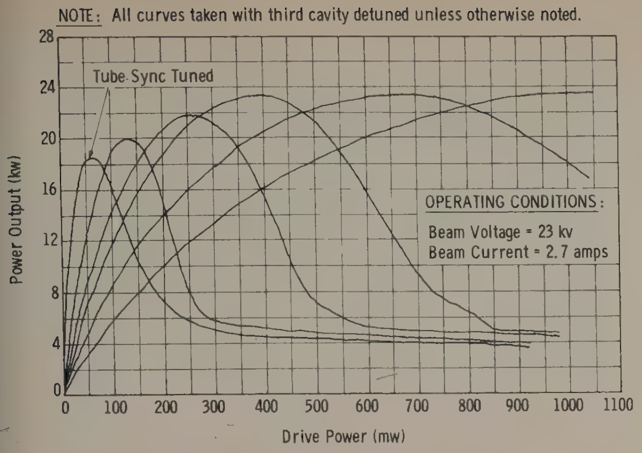

Figure 2 — Power output as a function of drive power.

tailed design of this tube, some comments relating to the design and performance characteristics are in order.

## II. Design Considerations

As a result of development work performed at Varian Associates during the last few years on X-band klystron amplifiers in the one to five kilowatt range, it became apparent that a 20 kilowatt c-w amplifier could be made without extensive improvements in the most critical items of design such as the beam optics, r-f cavities, and output windows.

Because of the difficulties encountered even at low power levels in the design of wide tuning range cavities and broad-banded window, it was decided to minimize these problems by making a tube with a narrow tuning range. In order to simplify the problem associated with finding a suitable driver tube the power gain was made sufficiently high so that the tube could be driven to full r-f output with an r-f input power of one watt. Thus, the VA-849 was designed to be a four cavity klystron amplifier to operate in the frequency band of 7.125 Gc to 8.50 Gc with individual tubes covering a frequency range of 60 Mc. This tuning is accomplished by moving a wall of the cavity. This motion inductively tunes the cavity by changing the volume of the cavity.

The electron beam is emitted from a Philips Type B impregnated cathode and focused by conventional Pierce gun techniques. In its transit through the drift tube the beam's radial motion is constrained by an axial magnetic field, and following the drift tube transit, the electron beam is permitted to spread into a magnetic-field-free, water-cooled collector. These techniques are well known in the microwave tube art, and all that was required to make a suitable beam for the VA-849 was somewhat greater care in attention to details. The optics of the VA-849 are such that with full power output approximately one to two per cent of the beam current is intercepted by the body of the tube, and the resulting power dissipation is easily removed with water cooling.

The r-f cavities are essentially "pill box" in shape with doubly re-entrant drift tubes. In order to obtain both high thermal and electrical conductivity, the cavities are fabricated with OHFC copper. With careful finishing of parts it is possible to achieve cavity $Q_0$s of approximately 5000; however, even so, almost one kilowatt of average r-f power may be dissipated within the output cavity due to the high circulating currents necessarily present; accordingly, it is necessary to water cool this cavity

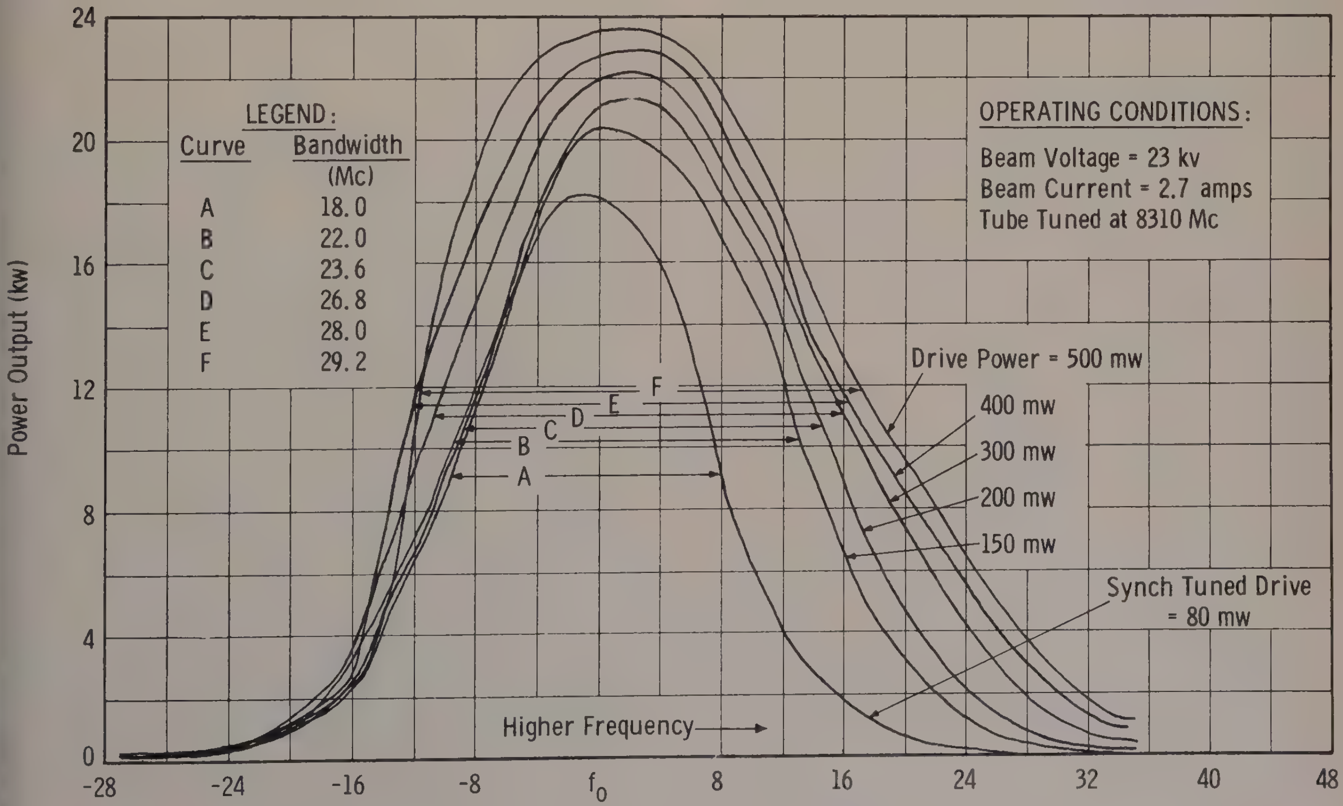

Figure 3 — Third cavity detuned bandwidth.

A paper by Vokes and Lea-Wilson[1] has an excellent discussion of instability problems encountered in the development of X-band amplifier klystrons for the two kilowatt c-w region. These instabilities lead to power output versus drive power and drive frequency characteristics with discontinuous jumps and hysteresis effects. By carefully avoiding excessive beam interception on the drift tubes and by water cooling of the cavities, it was possible to obtain good thermal stability as is indicated in the curves of Figures 2 and 3. The r-f drive power can be adjusted for saturated power output or for low level power output without requiring retuning of the cavities.

The power is coupled out of the output cavity into the output waveguide and then transmitted through a high purity aluminum oxide "poker chip" window. Because of the narrow operating bandwidth required, one can easily design a window to be free of spurious modes over the region of interest, and other than being especially careful to keep the window free of dirt and particles, the windows receive no special attention. Figure 4 shows a waveguide window section which consists of a rectangular-to-circular-to-rectangular waveguide transition. The ceramic is located in the center of the circular section.

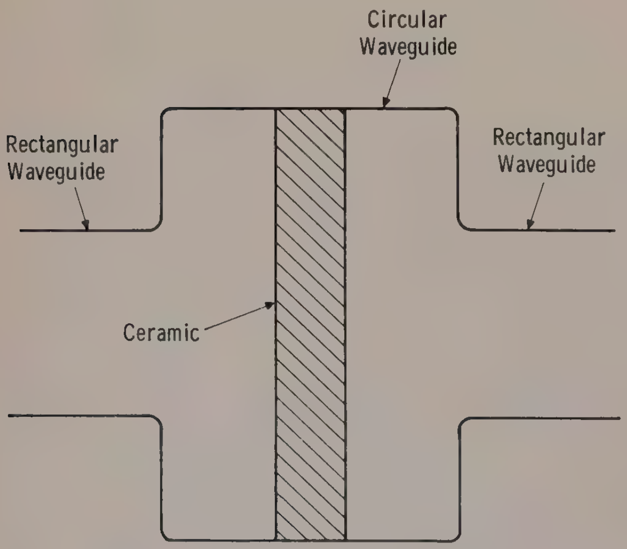

Figure 4 — Waveguide window section.

## III. Tube Performance

A photograph of the tube is shown in Figure 5 and in Figure 6 is shown the tube in its electromagnetic focusing structure. Some of the operating conditions are shown in Figure 7. Typical operating characteristics are listed both for the tube synchronously tuned and for the third cavity detuned. The tube can be operated either way. If it is necessary to obtain maximum gain the cavities may all be tuned to the same frequency (synchronously tuned). Most often, however, one is willing to sacrifice gain in order to obtain more efficient operation and higher power output. By detuning the third cavity high in frequency the efficiency is increased from 29 per cent to 38 per cent with a loss of 11 db in gain. In Figure 2 are shown curves of power output vs drive power for various amounts of third cavity detuning. Detuning the third cavity also increases the bandwidth of the tube. Figure 3 is a family of bandwidth curves. These curves indicate that the 3 db bandwidth can be increased from 18 Mc to 30 Mc due to the detuning. The data for Figures 2 and 3 were taken with an X-Y recorder and present a continuous plot of power output versus frequency and power output versus drive power with bolometer sensing elements used to sample the appropriate r-f powers.

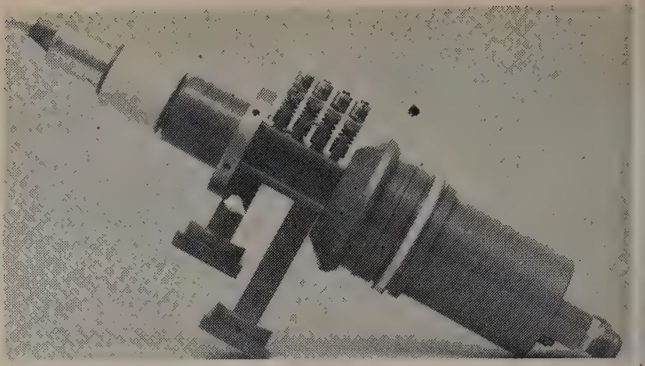

Figure 5 — VA-849 klystron.

Figure 8 is a plot of power output, beam current and efficiency as a function of beam voltage. At the operating voltage (23 kv) the efficiency synchronously tuned is slightly above 29 per cent. In other high power X-band tubes of modern design, efficiencies in excess of 40 per cent can be achieved. However, in the interest of minimizing beam interception, the clearance between the beam and the drift tubes was increased over what is used in the one to five kilowatt tubes. The tube which is being dis-

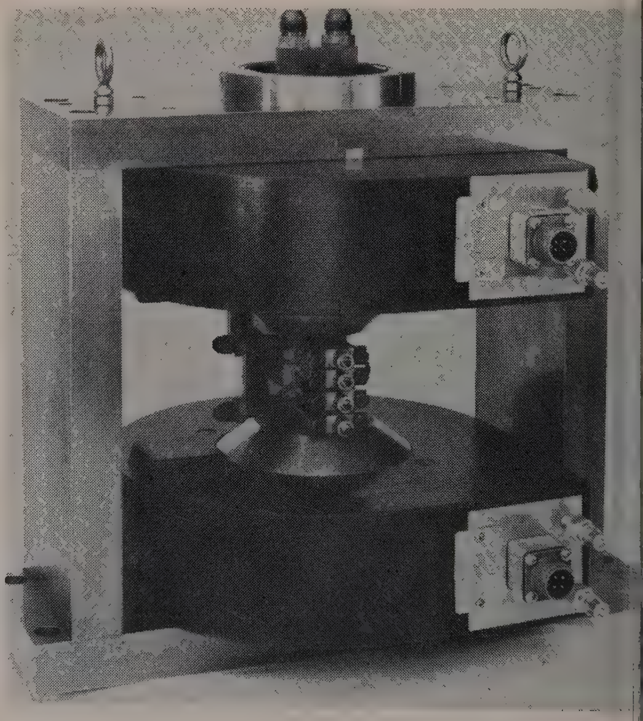

Figure 6 — VA-849 klystron in its electromagnet.

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[1] *J. C. Vokes and C. P. Lea-Wilson, "Instability Effects in High-Power CW Klystrons," Journal of Electronics and Control, Vol. 8, p. 401, June, 1960.*

VA-849 OPERATING CHARACTERISTICS

Maximum Ratings

| | |
|---|---|
| Power Output | 25 kw |
| Beam Voltage | 24 kv dc |
| Beam Current | 2.7 amps dc |
| Collector Dissipation | 65 kw |
| Body Current | 35 milliamps dc |
| Heater Voltage | 12.5 v |
| Heater Current | 5.1 amps |

General

| | |
|---|---|
| Frequency Range | 7.125 - 8.500 kMc |
| Tuning Range | 60 Mc |

(Tubes can be supplied that will tune any 60 Mc range between 7.125 and 8.500 kMc.)

| | |
|---|---|
| Magnet | VA-1549 Electromagnet |
| Weight | 14 lb for the tube<br>200 lb for the magnet |

Typical Operating Characteristics

| | Synchronously Tuned | Third Cavity Detuned | |
|---|---|---|---|
| Power Output | 18 | 24 | kw |
| Drive Power | 80 | 1000 | mw |
| Gain | 54 | 43 | db |
| Bandwidth (3 db) | 18 | 30 | Mc |
| Beam Voltage | 23 | 23 | kv dc |
| Beam Current | 2.7 | 2.7 | amps dc |
| Body Current (with drive) | 25 | 30 | milliamps dc |
| Efficiency | 29 | 38 | per cent |

Figure 7

cussed, the VA-849, operates with a beam power of approximately 60 kilowatts and a beam power density of about one megawatt per square centimeter; accordingly, it is quite important to do a good job of beam focusing. Extreme care is taken in the construction of the tube to insure that the magnetic field is parallel to the tube axis.

## IV. Waveguide Considerations

An important factor that cannot be overlooked in the use of high power X-band c-w amplifiers has to do with arc protection circuitry in the output waveguide. Any arcs that occur must be extinguished in an extremely short time (less than 10 $\mu$sec) to avoid breaking the output window. Care must be used in selecting the waveguide components to be used at this high power level. Sharp corners on the top or bottom of the guide must be avoided. Consequently, it is advisable to use side wall directional couplers. It is important that the flanges mate perfectly. Slight air gaps at the joints can be a serious source of arcs. Finally, it has also been found desirable to maintain a pressure of 10 lb gauge pressure of dry nitrogen in the waveguide. The above precautions still do not entirely eliminate the problems of waveguide arcs. For further protection a device is used on the output waveguide which will detect the occurrence of an arc and then quickly turn off the r-f drive to the tube.

The device that is being used obtains its signal from either of two sources. There is a photomultiplier tube arranged so that any light in the waveguide will trigger the device. Also there is a crystal detector arranged so as to give a signal proportional to the reverse power in the waveguide. This can be set to trigger the device when the load VSWR gets above some set value (no more than 1.25). Either signal can trigger a bistable multivibrator, the output of which controls the reflector voltage on the reflex klystron oscillator. The reflector voltage is shifted far enough to cause the tube to stop oscillating. The time required from arc occurrence to r-f drive removal has been measured to be less than 10 $\mu$sec for this device. So far, this response time has appeared to be adequate. Arcs have occurred with no damage to the tube using this equipment. Slower responding equipment (on the order of a millisecond) has been used without success.

An additional requirement for the transmission of these high powers is imposed on the waveguide components. Using high purity OFHC copper waveguide the losses are such that approximately one per cent of the power is lost per foot of waveguide. In order to remove this power it is necessary to cool all of the waveguide components. This can be done by circulating water through channels on the sides of the waveguide.

Figure 9 is a photograph of the experimental setup showing the tube, magnet, waveguide and test equipment. In order to appropriately evaluate the performance of the VA-849, it was necessary to acquire a load capable of dissipating the power generated by the tube. A standard Varian S-band water load in conjunction with a water-cooled tapered transition to X-band has been satisfactorily used up to a c-w power level of 51.5 kw.

## Conclusions

Tests performed on a number of VA-849 tubes demonstrate that 20 kw of c-w power at X-band can be generated by a klystron amplifier by paying careful attention to all the details in the design and construction of the tube. Control of the beam to minimize interception current on the body and adequate cooling of the r-f circuit is most important.

During the course of testing and evaluating the tube, a number of problems associated with the transmission of this high average power had to be resolved. Unplated, oxygen-free, high conductivity copper was found to be the best waveguide to use for minimum transmission loss. With this waveguide, the transmission loss as

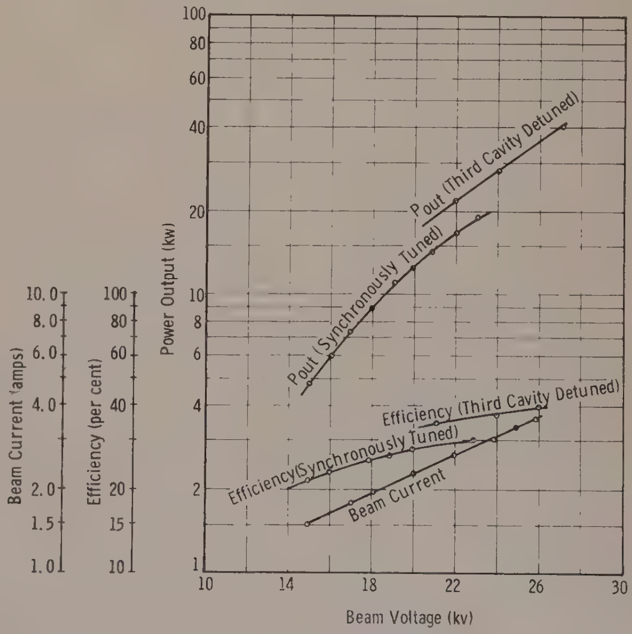

Figure 8 — Beam current, efficiency, and power output as a function of beam voltage.

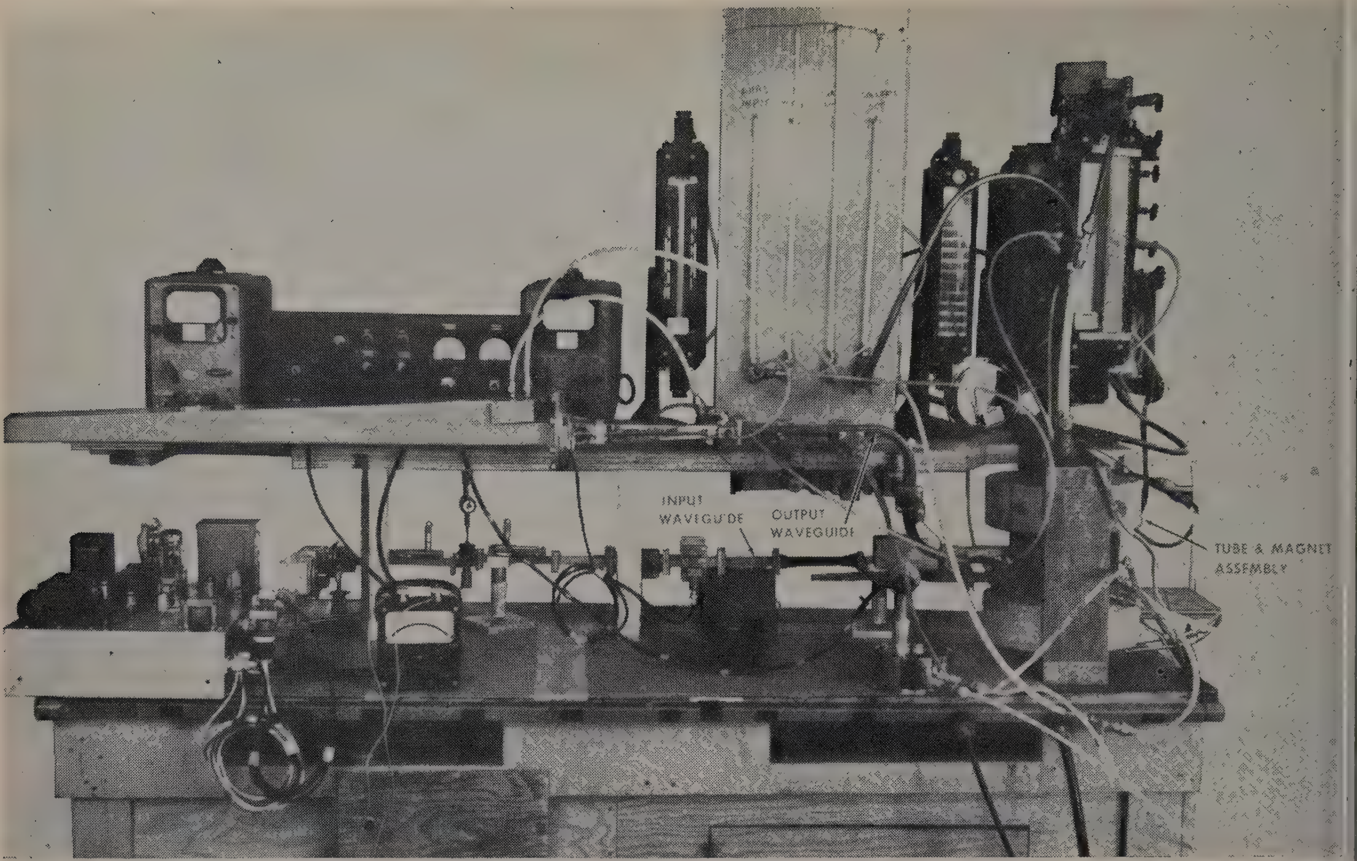

Figure 9 — Experimental test setup.

determined calorimetrically was approximately one per cent per foot and it was necessary to water cool all waveguide components in the output circuit to prevent overheating. Waveguide components were found to arc at much lower c-w powers than would be predicted based on field strength considerations. Waveguide arcs were found to have catastrophic effects on the output ceramic window on the tube, and it was necessary to pay particular attention to flanges and mating surfaces to prevent any sharp discontinuities. Pressurizing the waveguide to at least 10 psi also had a tendency to reduce arcs. To prevent damage to the tube in the event of an arc, it was necessary to design special equipment to remove the drive power in less than 10 microseconds.

Perhaps more significant than the performance obtained from the VA-849 are the implications as to the power generation capabilities which exist at lower frequencies. For example, $Pf^2$ scaling implies a capability of approximately one megawatt cw at 1100 Mc.

# GENERALIZED LINEAR RADAR ANALYSIS*

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## INTRODUCTION

It is well known that the response of an initially relaxed linear system to any excitation can be completely determined when either the impulse response or the step response of the system is known.[1] For a system composed of linear subsystems connected in cascade, the over-all system impulse response can be expressed in terms of the transfer functions of the individual cascaded subsystems.

A radar system consists of a cascaded transmitter, transmit antenna, target, receive antenna, receiver, and output indicator. This paper proposes a linear mathematical model for a radar system, and develops the transfer functions of the component subsystems. The mathematical model is then used to develop the radar system ambiguity function in range, doppler, and the two spatial angles.

## RADAR SYSTEM MODEL

### The Proposed Model is Shown in Figure 1.

*Transmitter*

Let $H_T(f)$ be the frequency spectrum of a transmitter. The frequency response of a filter is defined as the output spectrum divided by the input spectrum. Thus, the spectrum, $H_T(f)$, is produced at the output of a filter whose frequency response is $H_T(f)$ if its input is an impulse. The impulse generator and transmitter filter in Figure 1 represent the transmitter in a radar system.

*Transmit Antenna*

To develop the frequency response of the transmit antenna we must specify a pair of input terminals and a pair of output terminals. Let the input terminals be located far enough from the antenna proper so that only the dominant mode exists in the input transmission line at that point.[2] Let the output terminals be located unit distance apart in the plane of polarization of the antenna at the coordinates $(R,\theta,\phi)$ with respect to the antenna. The frequency response of the antenna as a function of $(f, R, \theta, \phi)$ is given by its steady-state output for an applied sinusoidal input of unit amplitude and frequency f for all $(f, R, \theta,$ and $\phi)$.

For example, the E-field steady-state $\theta$ plane response in the Fraunhofer region of a linearly polarized uniformly illuminated rectangular aperture which is large with respect to the signal wavelength is, for unit amplitude of illumination,[3]

$$H_{TA}(\omega, x) \propto [j\omega]\left[\frac{\sin \omega x}{\omega x}\right]\left[e^{-j\frac{\omega}{c}R}\right], \qquad (1)$$

where

$$x = \frac{d}{2c}\sin\theta$$

c = Velocity of propagation
R = distance to far field point
$\phi$ = zero.

The transfer function of a filter is also its frequency-domain impulse response. Thus, the Fourier transform of (1) gives the time-domain impulse response of the aperture.

From Fourier transform theory we know that multipli-

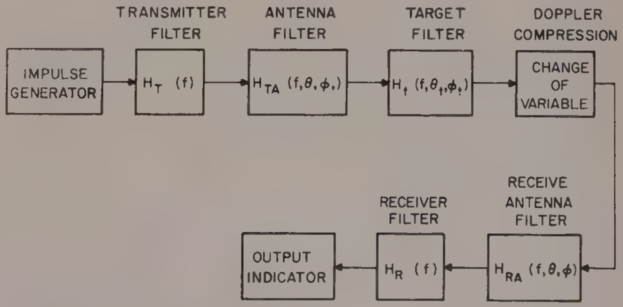

Figure 1 — Mathematical model of a linear radar system.

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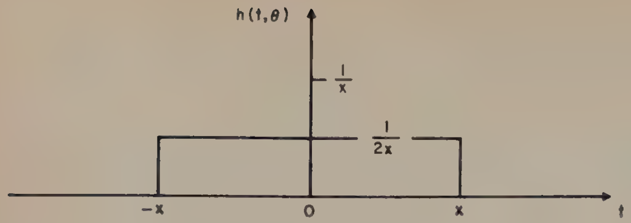
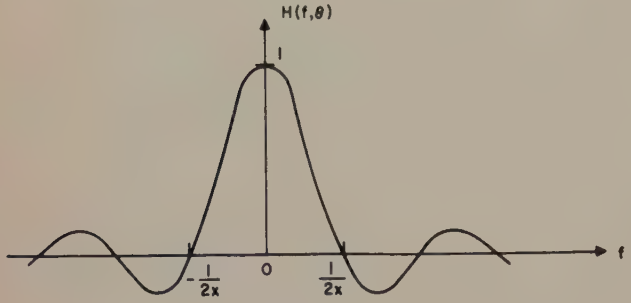
* *This work sponsored by the Air Research and Development Command, Rome Air Development Center, Griffiss Air Force Base, New York.*



(a) Impulse response



(b) Frequency response

Figure 2 — Filter characteristics.

cation of a spectrum by jω corresponds to differentiation of the time function. Thus, the first term in (1), [jω], represents a differentiation of the time function by the antenna. The term $\left[\frac{\sin \omega x}{\omega x}\right]$ corresponds to a frequency filter containing the angle θ as a parameter. Figure 2 shows the frequency response of this filter and its time-domain impulse response, h(t, θ). On boresight x=o, and the time domain impulse response is a unit impulse, while for x>o it is a rectangle of height $\frac{1}{2x}$ and unit area. The last term in (1), $\left[e^{-j\frac{\omega R}{c}}\right]$, is a time delay term due to the delay the waveform suffers in going from the antenna to the point in the far field.

Since the derivative of a unit step function is a unit impulse, the time-domain impulse response of the antenna is as shown in Figure 3. Figure 3 represents a positive impulse of area $\frac{1}{2x}$ located at $t=\frac{R}{c}-x$ and a negative impulse of area $\frac{1}{2x}$ located at $t=\frac{R}{c}+x$. At x=o, this becomes a unit doublet. Thus, the transmit time-domain boresight impulse response is a doublet.

If we know the spectrum of the input signal to the transmit antenna, we can find its far-field output by either convolving the time waveform of the input with the time-domain impulse response of the antenna or by multiplying the input spectrum by the antenna transfer function and then finding the time waveform of the resulting spectrum. For example, the far field of a continuous aperture uniformly illuminated by a sinusoidal pulse of time duration W is, from (1),

$$\psi(x, t)=\frac{1}{2\pi}\int_{-\infty}^{\infty}\frac{1}{\omega_1^{\,2}-\omega^2}\left[\omega_1-e^{-j\omega W}(\omega_1 \cos \omega_1 W+j\omega\sin\omega_1 W)\right]H_{TA}(\omega,x)\, e^{j\omega t}\, d\omega, \qquad (2)$$

where

$$\frac{1}{\omega_1^{\,2}-\omega^2}\left[\omega_1-e^{-j\omega W}(\omega_1 \cos\omega_1 W+j\omega \sin\omega_1 W)\right]$$

is the spectrum of a sinusoidal pulse extending from t=o to t=W. Figure 4 shows a plot of the magnitude of ψ(x,t) for the case where W is short compared with the propagation time corresponding to the aperture dimension d.[4,5] In Figure 4 the time axis origin has been shifted so that the origin occurs at the center of the far field radiated pulse.

The radiation from a uniform aperture illuminated by a rectangular sinusoidal pulse of time duration W has the following properties:

1. The radiated energy is spread over a time interval of W+2x where 2x is the projected time depth of the antenna.

2. For azimuth angles for which the projected time depth of the antenna, 2x, is less than the illuminating pulse length, W, the radiated pulse consists of an initial transient period equal in length to the projected time depth of the antenna, followed by a steady-state period equal in length to the difference between the illuminating pulse length and the projected time depth of the antenna, followed by a final transient equal in length to the projected time depth of the antenna.

3. For azimuth angles for which the projected time depth of the antenna, 2x, is greater than the illuminating pulse length, W, the radiated pulse consists of an initial transient equal in length to the length of the illuminating pulse, followed by a period of zero radiation equal in length to the difference between the projected time depth of the antenna and the length of the illuminating pulse, followed by a final transient equal in length to the illuminating pulse.

4. In the steady-state region |ψ(x,t)| varies with x as $\frac{\sin x}{x}$. In the transient regions ψ(x,t) varies smoothly as $\frac{1}{x}$.

By reasoning similar to that used for the uniformly illuminated aperture, it can be shown that the transfer function from the maximum aperture illumination to a far-field point for a rectangle aperture with a cosine taper in both planes is for the θ plane,

$$H_{TA}(\omega,x) \propto [j\omega]\left[\frac{\cos \omega x}{1-\left(\frac{2x}{\pi}\,\omega\right)^2}\right]\left[e^{-j\frac{\omega}{c}R}\right]. \qquad (3)$$

Similar interpretations can be placed on the terms of (3) that were placed on those of (1). Ignoring the last term in the right side of (3), the time-domain impulse

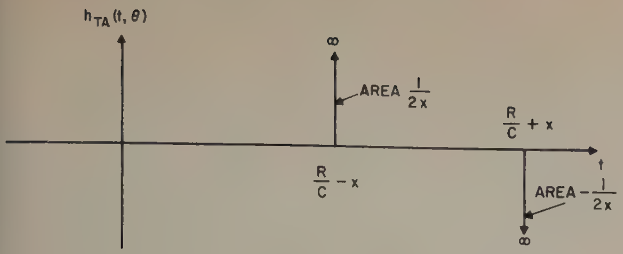


Figure 3 — Impulse response of uniform aperture.

response corresponding to (3) is

$$h(t,x)=\frac{-\pi^2}{8x^2}\sin\frac{\pi t}{2x}, -x<t<x \qquad (4)$$

$$h(t,x)=0 \qquad \text{elsewhere.} \qquad (5)$$

Figure 5 is a plot of (4) and (5). It is seen that as $x \rightarrow 0$ (4) approaches the unit doublet.

To have a time-domain impulse response at a point in the far-field which is an impulse, a transmit antenna must transmit all frequencies equally well to that point with linear phase. Thus a matched antenna which is large with respect to wavelength, $\lambda$, cannot have a transmit impulse response which is an impulse. An impulse has a spectrum that is uniform over all frequencies. An antenna cannot be large with respect to $\lambda$ for all frequencies nor matched for all frequencies. However, as long as it meets the conditions we specify over all frequencies which we intend to apply to it, we can assume for analytical purposes that it meets the conditions for all frequencies.

It can be shown that the frequency domain transmit impulse response for a matched antenna satisfies the following relationships.[6]

$$|H_{TA}(\omega,0,0)|^2=\frac{\eta}{Z_0}\,\frac{G}{4\pi R^2}, \qquad (6)$$

where G is the antenna directivity and $Z_0$ is the characteristic impedance of the transmission line feeding the antenna; and

$$\int_0^{2\pi}\int_0^{\pi}|H_{TA}(\omega,\theta,\phi)|^2 \sin\,\theta\, d\theta\, d\phi=\frac{\eta}{Z_0}\,\frac{1}{R^2}. \qquad (7)$$

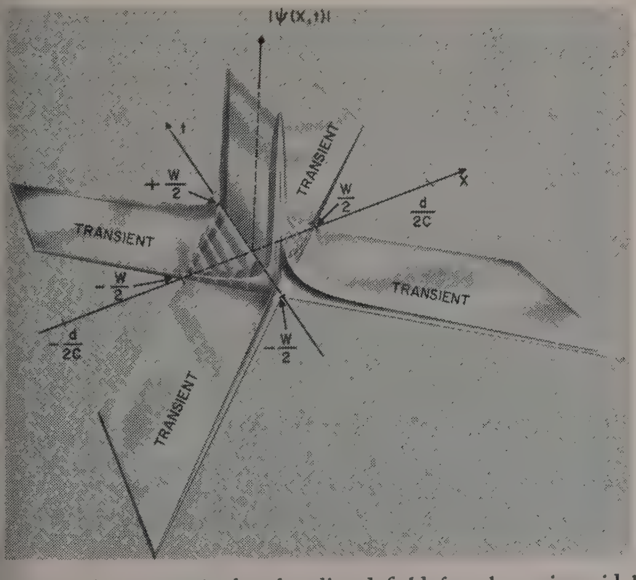


Figure 4 — Magnitude of radiated field for short sinusoidal pulse and uniform aperture.

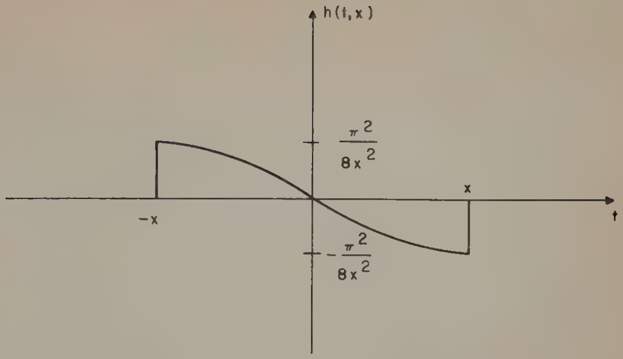


Figure 5 —Time-domain impulse response of aperture with cosine taper.

*Target*

In a radar system the target can be considered to be a linear device which receives a signal spectrum from the transmit antenna and radiates some new spectrum in the direction $\theta_t$, $\phi_t$ where $(R, \theta_t, \phi_t)$ are a set of coordinates with origin located at the target and moving in translation with respect to the coordinates of the radar system. For most targets the radiated spectrum at any instant of time varies greatly with changes in $\theta_t$, $\phi_t$ and for a given $\theta_t$, $\phi_t$ varies also with time. In this paper it is assumed that the target is a point target and that the receive antenna is sufficiently small so that the effects of doppler are the same across the receive antenna. The effects of target cross-section are neglected by assuming that the return echo has, except for doppler effects, a spectrum identical to that of a point located at $(2R, \theta, \phi)$ in the transmit antenna far field, where $(R, \theta, \phi)$ are the coordinates of the target.

Doppler results in compression or expansion of the frequency spectrum about the spectrum origin. Let

$$\rho=\frac{c+v}{c-v} \qquad (8)$$

where

c = velocity of light
v = target velocity

For a target approaching the radar set, the spectrum of the reflected signal is

$$\left|\frac{1}{\rho}\right|^{1/2} H_T\left(\frac{f}{\rho}\right) H_{TA}\left(\frac{f}{\rho}, \theta, \phi\right).$$

For a constant velocity, $\left|\frac{1}{\rho}\right|$ is a constant and for computational purposes it can be assumed that the echo spectrum is

$$H_T\left(\frac{f}{\rho}\right) H_{TA}\left(\frac{f}{\rho}, \theta, \phi\right). \qquad (9)$$

### *Receive Antenna*

That an antenna does not in general have the same impulse response on receive as on transmit can be seen qualitatively from Figure 6. A and B are identical antennas each matched to a resistive line of impedance $Z_o$ over the frequency band of interest. The generator connected to A generates a sinusoid of frequency $\omega$. The transmit boresight frequency domain impulse response as a function of $\omega$ is given by $E_2/E_1$ as $\omega$ is varied over all frequencies. $E_1$ is the input voltage across a selected pair of terminals on the transmission line connected to A, and $E_2$ is the voltage across 1 meter of space in the plane of polarization in the far field. Due to the concentration of the transmit power in a narrower beam as the frequency is raised, $E_2$ increases directly as $\omega$ if $E_1$ is held constant. Thus, the transmit time-domain boresight impulse response must be some constant times a unit doublet.

Assume antenna A to be ignored in Figure 6 and that by some means a plane wave is generated at $E_2$ which travels toward antenna B. The volts per meter of this plane wave at $E_2$ is held constant and its frequency, $\omega$, is variable. The receive boresight frequency-domain impulse response of antenna B as a function of $\omega$ is given by $E_3/E_2$. If $E_2$ is held constant then as $\omega$ is varied the watts per square meter in the incident field at B remains constant, the effective aperture of antenna B remains constant, and $E_3$ remains constant. Thus, the receive time-domain boresight impulse response is a constant times a unit impulse.

It should be noted that the input terminals to the antenna on receive were considered to be two points 1 meter apart in the plane of polarization and located just in front of the physical aperture of the antenna. These could just as well be located at some distance, R, from the antenna. However, since on receive it is not always known at what distance from the antenna the wave originated, it seems best to consider the variation in field strength due to range in any particular system to be associated entirely with the transmit antenna.

The relationship between the transmit impulse response and the receive impulse response of an antenna is in general a function of how the antenna is terminated. For the important special case of a matched antenna we can derive this relationship. Silver[7] has shown that for a matched antenna

$$A_r(\theta,\phi) = G(\theta,\phi)\,\frac{\lambda^2}{4} \qquad (10)$$

where

$A_r(\theta,\phi)$ = receive cross section presented by the antenna to a plane wave incident from the direction $(\theta,\phi)$, commonly called effective area.

$G(\theta,\phi)$ = directivity.

$\lambda$ = wavelength of electromagnetic field.

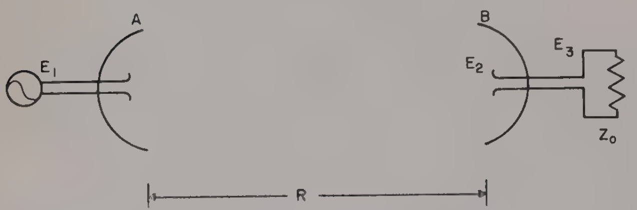


Figure 6 — Transmit-receive link using identical antennas.

Thus, as is generally accepted, for any given frequency the normalized receive pattern and the normalized transmit pattern of a matched antenna are identical. However the (unnormalized) transmit and receive patterns are related by a function of $\omega^2$ as shown by (10).

For a matched antenna that is large compared to $\lambda$, (10) becomes

$$A_r\,(\omega,\theta,\phi) = G\,(\omega,\theta,\phi)\,\frac{\lambda^2}{4\pi} \qquad (11)$$

$G\,(\omega,\theta,\phi)$ can be considered to be the ratio of the powe radiated in direction $(\theta,\phi)$ per unit solid angle to th average power per unit solid angle or considered to be th ratio of the watts per square meter at range R in the direction $(\theta,\phi)$ to the average watts per square meter a range R.

In Figure 6 let $(R,\theta,\phi)$ describe the spatial location of the points $E_2$ with respect to antenna A and $(\theta,\phi$ also describe the angle of arrival of the receive wave a antenna B. Then

$$\frac{|E_2|^2}{2\eta}\,A_r\,(\omega,\theta,\phi) = \frac{|E_3|^2}{2Z_o} \qquad (12)$$

where $\eta$ = impedance of free space. Also

$$G\,(\omega,\theta,\phi) = \frac{Z_o}{\eta}\,\frac{|E_2|^2}{|E_1|^2}\,4\pi R^2 \qquad (13)$$

Combining (11), (12), and (13) gives

$$\frac{|E_3|}{|E_2|} = \frac{Z_o}{\eta}\,\frac{2\pi Rc}{\omega}\,\frac{|E_2|}{|E_1|}\,. \qquad (14)$$

(14) gives the relationship between the frequency domain transmit impulse response of an antenna and it frequency-domain receive impulse response except fo phase angle. There are two factors which cause the phas angle of the transmit impulse response to differ from tha of the receive impulse response. One is the difference i range delay due to the different choices in spacing of th hypothetical input and output terminals. The other is du to the fact that the far field from an element of electri current is advanced in phase 90° for all frequencies ove the phase angle due to range delay alone, while the electric current induced in a conducting surface is in tim phase with the incident field producing it. Hence,

$$H_{RA}\,(\omega,\theta,\phi) = \frac{Z_o}{\eta}\,\frac{2\pi Rc}{j\omega}\,e^{+j\frac{\omega R}{c}}\,H_{TA}\,(\omega,\theta,\phi). \qquad (15)$$

For computations where multiplicative constants an time delay are of no consequence, and where the signal i sufficiently narrow band so that differentiation is equivalen to a phase shift, the transmit and receive impulse responses of an antenna may be assumed to be same.

It can be shown that the frequency-domain receive impulse response for a matched antenna satisfies the following relationships:[8]

$$|H_{RA}\,(\omega,0,0)|^2 = \frac{Z_o}{\eta}\,A_{em} \qquad (16)$$

where $A_{em}$ is the maximum effective aperture of the antenna, and

$$\int_0^{2\pi}\int_0^{\pi} |H_{RA}(\omega,\theta,\phi)|^2 \sin\theta \, d\theta \, d\phi = \frac{Z_o}{\eta}\lambda^2 \qquad (17)$$

It is also shown that for identical matched antennas,

$$|H_{TA}(\omega,0,0)|^2 \quad |H_{RA}(\omega,0,0)|^2 = \left[\frac{A_{em}}{\lambda R}\right]^2 \qquad (18)$$

and

$$\int_0^{2\pi}\int_0^{\pi} |H_{TA}(\omega,\theta,\phi)|^2 \quad |H_{RA}(\omega,\theta,\phi)|^2 \sin\theta \, d\theta \, d\phi = \frac{\lambda^2}{R^2}\frac{B_2}{B^2}, \qquad (19)$$

where B is the beam area of the antenna and $B_2$ is the beam area of an antenna having a normalized power pattern equal to the square of the normalized power pattern of the array in question. (18) is the Friss[9] power transmission formula for two similar matched antennas separated by a distance R and boresighted on each other.

*Receiver*

The receiver is assumed to consist of matched filtering on boresight with zero doppler. Thus

$$H_R(f) = [H_T(f) \ H_{TA}(f,0,0) \ H_{RA}(f,0,0)]^* \qquad (20)$$

where * denotes the complex conjugate.

*Output Indicator*

The output indicating device will be ignored. It will be assumed that the radar system output is the voltage out of the receiver matched filter.

## GENERALIZED RADAR AMBIGUITY FUNCTION

The output signal spectrum, $S_o$, for a target approaching the radar with a velocity v is

$$S_o = H_T\left(\frac{f}{\rho}\right) H_{TA}\left(\frac{f}{\rho},\theta,\phi\right) H_{RA}(f,\theta,\phi) \ H^*_T(f) \ H^*_{TA}(f,0,0) \ H^*_{RA}(f,0,0). \qquad (21)$$

The output signal waveform is then,

$$\psi(\tau,\theta,\phi,\rho) = \int_{-\infty}^{\infty} H_T\left(\frac{f}{\rho}\right) H_{TA}\left(\frac{f}{\rho},\theta,\phi\right) H_{RA}(f,\theta,\phi) \qquad (22)$$

$$H^*_T(f) \ H^*_{TA}(f,0,0) \ H^*_{RA}(f,0,0) \ e^{j2\pi f\tau} df.$$

If we assume that the transmitter is connected directly to the receiver by a transmission line which is capable of introducing a doppler compression on the signal and further assume that the system is sufficiently narrow band so that doppler compression can be represented by a simple frequency shift, $\alpha$, then (22) becomes

$$\psi(\tau,\alpha) = \int_{-\infty}^{\infty} H^*_T(f) \ H_T(f+\alpha) \ e^{+j2\pi f\tau} df. \qquad (23)$$

$\psi(\tau,\alpha)$ is the radar ambiguity function of Woodward.[10,11] (23) expresses the extent to which the output of the radar system is ambiguous in the range-doppler plane. Figure 7 shows a plot of the $|\psi(\tau,\alpha|^2$ for a single-tone pulse.[12] For the least ambiguity one would like a waveform having an ambiguity function that is zero everywhere in the range-velocity plane except for a single spike. Similarly, (22) expresses the extent to which the output of the radar system is ambiguous in the four dimensional space of range, doppler, and the two spatial angles.

Woodward showed for his ambiguity function that the ratio of the peak height of the magnitude of the function squared to the volume under the magnitude of the function squared was a constant. This indicates that the total ambiguity is independent of the waveform chosen. Applying this same test to (22), we obtain[13]

$$\frac{|\psi(0,-1,\ 0,0)|^2}{\iiiint |\psi(\tau,u,\phi,\alpha)|^2 \, d\tau du d\phi d\alpha} = \frac{1}{B_o} \qquad (24)$$

where $u = -\cos\theta$ and $B_o$ is the receive antenna beam area at frequency $f_o$ within spectrum $H_T(f)$. For symmetrical spectrums of 10 per cent bandwidth or less $f_o$ is to a good approximation the spectrum center frequency. For wider symmetrical spectrums $f_o$ is slightly lower than the center frequency, indicating a slight increase in ambiguity for very wide bandwidths.[13]

Equation (24) assumes:

1. The target is in the far field of the antenna.
1. The signal doppler is the same across the face of the antenna.
3. The return signal differs from the transmit signal only by doppler effects.

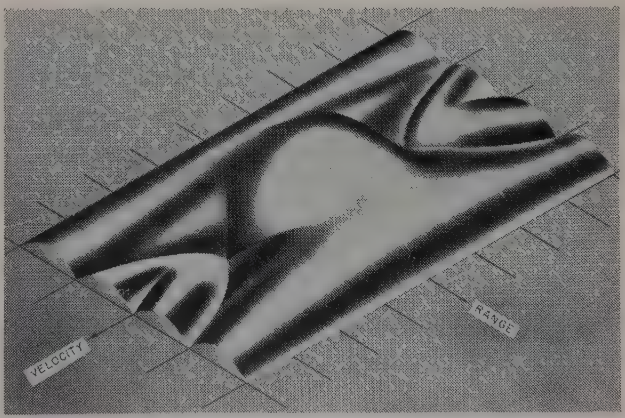
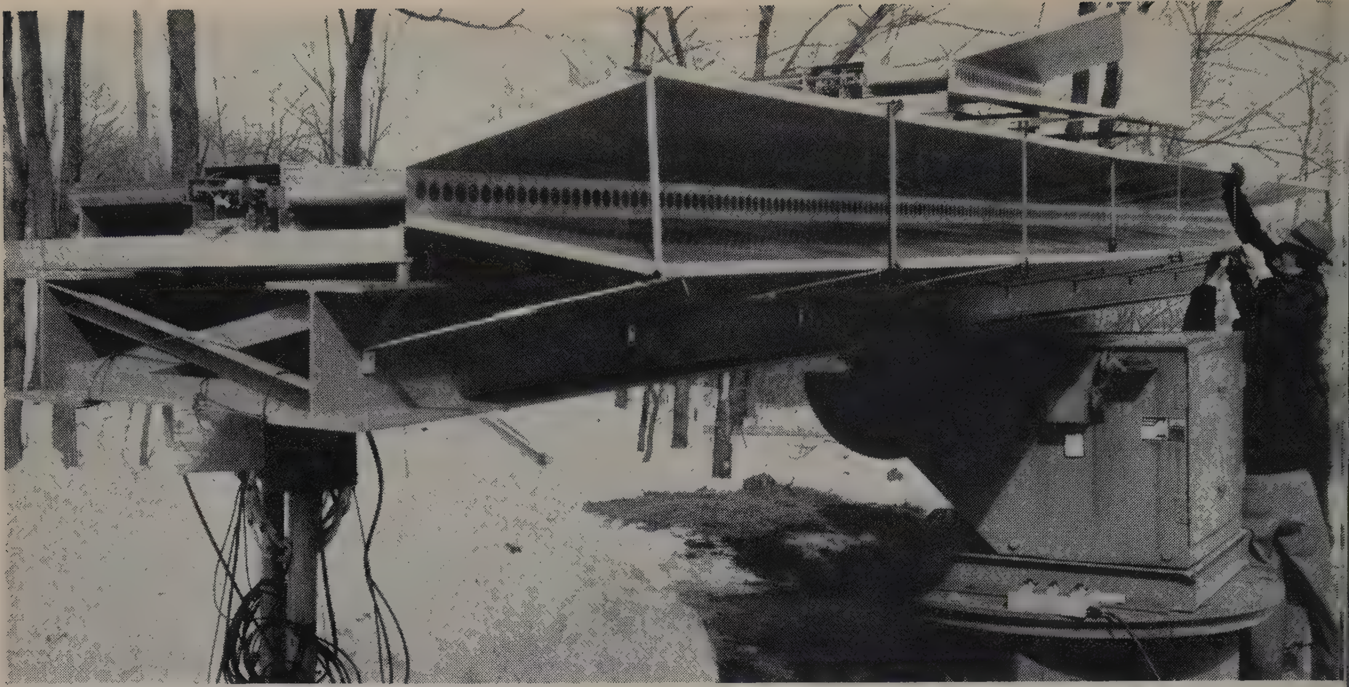


Figure 7 — Ambiguity function of a single-tone pulse.



Developmental 192-element electronically scanned array antenna shown being tested represents the current trend toward increasingl flexible, higher performance antennas for radars and satellite communications. An operational system would contain many thousand of such elements. The complexity of this type of antenna, plus system requirements for increased angular resolution (meaning larg aperture) and improved range resolution (meaning short pulse length) introduce a fundamental interaction between antenna desig and signal processing techniques. *(Photograph Courtesy of General Electric Company*

4. The transmit antenna is a matched isotropic radiator.

Equation (24) shows that the total ambiguity is a function of only the beam area, $B_o$, and is essentially independent of the waveform used. Thus, for linear systems one cannot spoil the antenna beam area and then remove the resulting ambiguity by broadening the signal spectrum as long as the same spectrum center frequency i maintained. However, just as coded waveforms are usefu against specific target configurations, so it may be tha optimum combinations of waveforms and antenna exis for particular target configurations.

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# RECENT ADVANCES IN LOW-NOISE TRAVELING-WAVE TUBES

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FIRST OF TWO PARTS

## Types and Categories of Low-Noise Traveling-Wave Tubes

The sensitivity of a traveling-wave tube is limited by the amount of noise generated within the tube and is usually described in terms of noise figure, the difference between the input and output signal-to-noise ratios expressed in decibels.

When no beam current is flowing in a traveling-wave tube, the tube acts as a microwave attenuator having an attenuation usually in excess of 50 db. With rated beam current, the tube is an amplifier having high gain. However, the electron beam used to amplify microwave signals also amplifies its inherent noise spectrum. If the electron beam were generated from a gun designed without regard for noise-reduction techniques, the tube noise figure would range from 25 to 40 db. Although such a tube might perform well as an amplifier at medium- and high input-signal levels, it could not detect very-low-level input signals. Therefore, the traveling-wave tube must be designed as a low-noise device in which the contribution of beam noise to the output signal is minimized.

Modern forward-wave traveling-wave tubes specifically designed for low-noise operation are of two types: medium-low-noise and low-noise tubes having noise figures from 4.5 to 16 db, and developmental ultra-low-noise tubes having noise figures less than 4.5 db.

This paper is concerned with tubes of both types. New advances such as techniques for reduction of noise figure, miniaturization, and the use of periodic-permanent-magnet focusing are described, in addition to the electrical performance representative of many different varieties of medium-low-noise and ultra-low-noise tubes.

Since 1957, major development efforts have been directed toward the development of low-noise traveling-wave tubes as the result of the growth of radar, electronic countermeasures radar, and missile and satellite systems. Consequently, much progress has been made toward a wide variety of objectives, from tubes of very lowest noise figure to tubes where noise figure is secondary in importance to such considerations as weight and ruggedization.

Low-noise traveling-wave tubes may be grouped in several distinct categories according to noise figure, bandwidth, and weight of focus structures. Table I indicates that when weights of the order of 2 to 3 pounds and very wide bandwidths are important, noise figures are quite high, ranging from 10 to 15 db. On the other hand, when bandwidth, weight, and size are secondary in importance

TABLE I: PERTINENT PARAMETERS FOR LOW-NOISE TUBES RELATING WEIGHT, MAGNETIC FIELD, AND FOCUS STRUCTURE WITH NOISE FIGURE.

| NOISE FIGURE (db) | 2000-to-4000-MEGACYCLE FREQUENCY OCTAVE (per cent) | FOCUS STRUCTURE | PEAK GUN MAGNETIC FIELD (gausses) | WEIGHT OF TUBE PLUS FOCUS STRUCTURE (pounds) |
|---|---|---|---|---|
| under 4.5 | 20-40 | Solenoid | 800 (taper field) | 40 |
| 4.5-6 | 40-100 | Solenoid | 525 | 40 |
| 6-8 | 40-100 | Solenoid | 525 | 20-40 |
| 8-11 | 100 | Solenoid | 400 | 7 |
| 11-16 | 100 | PPM | 200 | 3 |

to noise figure, solenoids having magnetic fields of very high intensity can be used to provide noise figures of less than 4 db.

As a result of recent advances in tube design, ultra-low-noise traveling-wave tubes are now providing lower noise figures than many parametric amplifier and circulator combinations. Because low-noise traveling-wave tubes have much greater stability and reliability than comparable solid-state microwave amplifiers, particularly at S-band and higher frequencies, the trend in many communication systems, after a period of emphasis on solid-state amplifiers, is toward a return to the hot-cathode electron-beam-type traveling-wave amplifier as a low-noise amplifier.

## NOISE REDUCTION IN TRAVELING-WAVE TUBES

### Low-Noise Traveling-Wave-Tube Structures

Traveling-wave tubes, like conventional low-frequency wide-band amplifiers, require input and output circuits having the proper bandwidth and impedance characteristics. The circuits used to couple rf signals into and out of the helix are similarly included as part of the amplifier package. Consequently, the final package is a complete amplifier stage and not just a tube as customarily defined in low-frequency systems.

Low-noise traveling-wave-tube amplifiers consist of the following components:

(a) a long slow-wave structure (such as a helix),

(b) a low-noise electron gun which projects an electron beam through the helix,

(c) an input coupler which applies the signal to be amplified at the start of the helix,

(d) an output coupler which extracts the amplified signal from the end of the helix,

(e) an attenuator on the helix which prevents reflected-wave oscillations, and

(f) a focus structure which focuses the electron beam from the gun through the helix to a collector.

Of these components, only the low-noise electron gun is not common to all traveling-wave tubes.* It is this unique structure which primarily determines the noise figure of the tube during amplification.

The cathode of the electron gun emits random numbers of electrons having random velocities, and the resultant space-charge fluctuations contribute noise components to the electron beam produced by the gun. The low-noise electron gun provides an electron beam in which noise components have been minimized near the cathode. Thus, the potential profile presented to the electron beam along the beam axis in the gun causes the remaining noise components in the beam to have minimum effect in the helix amplifying region. By means of such a gun, noise figures can be reduced from about 25 to 35 db (characteristic of traveling-wave tubes using conventional electron guns such as the magnetic-field-free Pierce-type convergent-flow guns) to noise figures substantially less than 4 db.

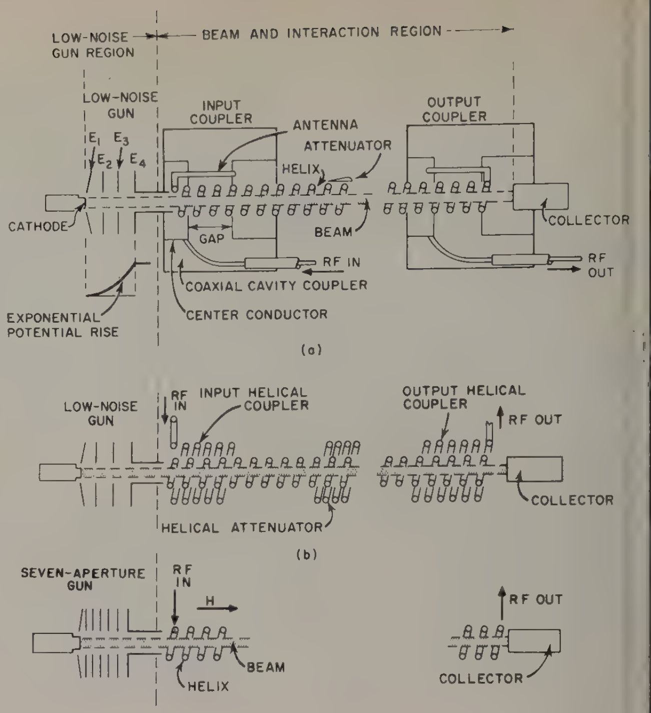

Figure 1 — Detail of low-noise tubes using (a) coaxial-cavity rf couplers, and (b) helical rf couplers.

Some of the basic structures of the low-noise traveling-wave tube are illustrated in Figure 1, which shows details of the low-noise electron gun, the nonresonant helical slow-wave structure along which the wave to be amplified travels and through which the low-noise electron gun projects the electron beam, the input and output rf couplers, and the collector. When the velocities of the traveling wave and the beam are equal (synchronous operation), interaction between the electron beam and the traveling wave produces electron bunching in a phase such that energy is transferred from the electron beam to the traveling wave. The wave, therefore, emerges from output couplers at the end of the helix with a power gain.

Figure 1(a) shows the basic construction of one type of coaxial-cavity rf coupler which is used as an input or output coupler. Each coaxial-cavity coupler has a gap coupled to an antenna connected to one end of the helix. Such couplers are large in size, but provide coupling with minimum insertion loss for frequency ranges from L-band through C-band.

The rf couplers shown in Figure 1(b) consist of helices concentric with the main helix, which couple energy to or extract energy from the main helix. Helical couplers, although more lossy than coaxial-cavity couplers, are capable of coupling over bandwidths in excess of an octave. Moreover, their small size makes them suitable for use in tubes having restricted volume.

An attenuator couples attenuation into the helix at a point between the input and output couplers to prevent reflected waves and backward waves in the electron beam from starting oscillations. The tube shown in Figure 1(a) uses Aquadag*-coated rods to introduce the attenuation; a coupled helix of lossy wire introduces the attenuation into the tube shown in Figure 1(b).

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* *Low-noise electron-gun techniques have also been adapted to klystron operation, providing a noise figure of 6.7 db in S-band, as reported by R. G. Rockwell, "Are Klystron Amplifiers Inherently Noisy," WESCON Record, Pt 3, 1958.*

Figure 2 is a photograph of the solenoid and capsule arrangement of a low-noise traveling-wave tube using the coaxial-cavity couplers of Figure 1(a). Figure 3 shows both coaxial-cavity and helical rf couplers and the low-noise electron tubes to which they couple. The bulk of the coaxial-cavity couplers is evident from this photograph.

The slow-wave helix of the tube using coaxial couplers is supported by three ceramic rods located within the glass envelope. The helix of the tube using helical couplers is supported by the fluted, or ridged, inner surface of the glass envelope. The helical couplers couple through the glass envelope directly to the main helix.

Another type of coupler, not shown, is the waveguide coupler, which couples rf to an antenna attached to one end of the helix. Waveguide couplers provide the advantage of low insertion loss with wide bandwidth, and are especially practical at C- and X-band because of reduced size.

## The Transformer and Cathode Regions of Low-Noise Electron Guns

The low-noise electron gun acts as an impedance transformer between the cathode and the entrance to the helix and, in general, includes the following three regions shown in Figure 4:

(a) the cathode; i.e., the source of the electrons whose random fluctuations comprise the noise in the electron beam;

(b) the virtual cathode or beam-launching region; i.e., the short region in front of the emitting surface where the fluctuations of the electron velocity are comparable in order of magnitude to the average velocity;

(c) the impedance transformer or gun region extending from the cathode region to the entrance of the helix. In this region the velocity fluctuations are small compared with the average velocity.

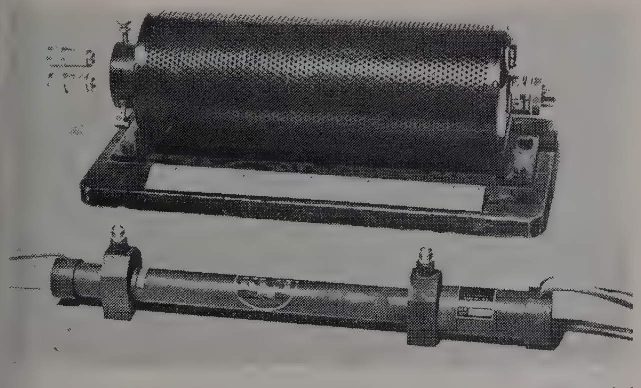

Figure 2 — Solenoid-focused low-noise tube using coaxial-cavity rf couplers.

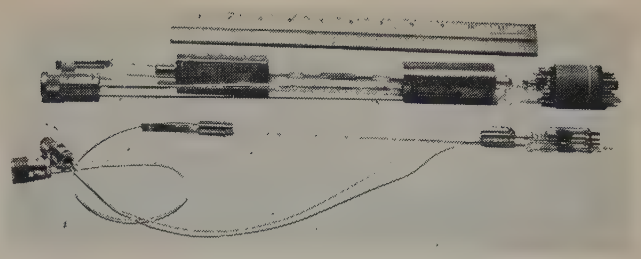

Figure 3 — Coaxial-cavity-coupled electron tubes using ceramic-rod helix support (above) and helical-coupler-coupled electron tubes using flute-supported helices (below).

Low-noise traveling-wave tubes in the 6-to-16-db noise figure range derive their low-noise characteristics from proper design and use of the cathode and the impedance transformer or gun region. Traveling-wave tubes designed for operation in the noise-figure range of less than 6 db derive their ultra-low-noise characteristics from proper design and use of *both* the beam-launching region and the transformer region, in addition to the use of a cathode having optimum characteristics.

## The Exponential-Transformer Electron Gun

A practical approach to utilization of the transformer region was contributed by Eichenbaum and Peter[1], who analyzed the exponential-transformer gun. This gun is of the general type shown in Figure 1(a). It consists of a small, flat cathode that projects a substantially parallel flow of electrons through a series of apertures arranged between the cathode and the drift-tube entrance of the helix and is immersed in an axial magnetic field. The electrons pass successively through the apertures from the cathode region to the drift tube; the apertures are biased to present an exponential rise in potential to the electrons. This rise in potential causes the electron gun to act as an exponential *matching transformer* between the impedances presented by the cathode region and the entrance to the helix.

Although many different types of electron guns could be devised to function as low-noise electron guns, the exponential transformer has several decided advantages. It is noncritical in operation, can be analyzed by known and well-understood classical exponential transmission-line theory, and accelerates the beam smoothly without potential discontinuities. In addition, the resulting transformer region of the gun is very short in length and is very broad-band in operation.

The pre-helix region determines the standing-wave ratio

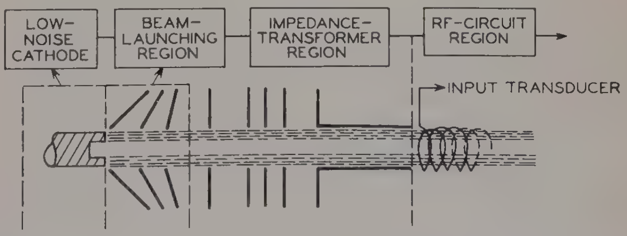

Figure 4 — Diagram of a low-noise electron gun showing the various regions of the multiple-aperture electron gun which controls noise figure.

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* *Registered trademark; Acheson Colloids Co.*

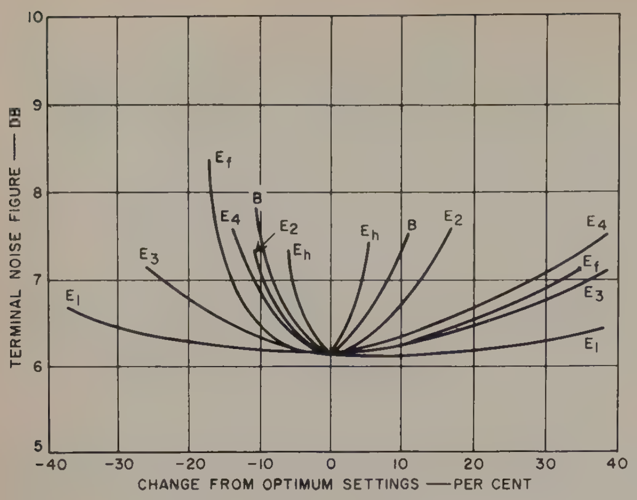

Figure 5 — Change in terminal noise figure as a function of deviation from optimized lowest-noise voltages applied to the low-noise gun heater ($E_f$) and apertures, and deviation from optimum magnetic field (B) of a 6861 low-noise tube. $E_1$, $E_2$, $E_3$, and $E_4$ apply respectively to the successive apertures; $E_1$ applies to the aperture nearest the cathode.

and the phase of the noise currents in the beam at the entrance to the helix. These factors, in conjunction with the gain-determining parameters of the helix amplifying region, determine the noise figure of the traveling-wave tube. When these quantities are optimized for lowest-noise operation, the coupling of the noise components from the electron beam to the helix is greatly reduced. Noise-figure reduction to less than 6 db is possible through the use of the exponential transformer alone.

As mentioned previously, the noise-reducing action in the exponential-transformer gun is not very critical. Figure 5 illustrates this noncritical action by showing the variation in noise figure of an RCA-6861 tube using a four-aperture gun as a function of the deviation from optimum values of the voltages $E_1$, $E_2$, $E_3$, and $E_4$ on the four apertures, the heater voltage $E_f$, and the magnetic-field intensity B; $E_1$ is the voltage on the aperture nearest the cathode.

## Some Historical Aspects of the Low-Noise Electron Gun

The earliest investigation of traveling-wave-tube amplifiers as low-noise devices was made during the 1940's by Kompfner[3], who reported a measured noise figure of 11 db in 1946. In the early 1950's, measured noise figures of 8.5 db, 10 db, and 11 db were reported by Peter[2], Watkins[4], and Robinson and Kompfner[5], respectively.

During the late 1940's, an attempt was made by Pierce[6] to analyze the mechanism of noise in traveling-wave tubes and to predict a maximum value of noise figure based on full shot noise at the cathode. During this period, Cutler and Quate[7] and Smullin[8] also experimentally studied noise fluctuations in electron beams by sliding-probe measurements.

In the 1950's, the fundamental operation of the low-noise electron gun was further clarified by the recognition of the role of the beam cathode region in determining minimum noise figure.

Watkins considered the effect on noise performance when both thermal-velocity fluctuations and shot-effect current fluctuations were present in the beam. By considering noncorrelated thermal velocity and shot-noise current fluctuations, Watkins predicted minimum-noise figures which were studied in the so-called Watkins velocity-jump gun, an electron gun in which a succession of velocity jumps were provided to the beam. Bloom and Peter[9] described the electron gun in terms of an analogous transmission line having an impedance which is a function of the beam parameters at any point in the tube. Bloom and Peter derived conditions necessary for minimum noise figure which included (1) the standing-wave ratio of the composite of velocity and current noise waves at the helix entrance, and (2) the location of the current-standing-wave minimum with respect to the helix entrance.

In 1955, Bloom[10] published practical design curves for a noise-minimizing impedance transformation. In 1956, the validity of Bloom's and Peter's work was experimentally proved by Beam and Knechtli[11], who verified that optimum noise figures are obtained under the theoretically prescribed conditions. In 1959, the work on the exponential-transformer gun was culminated in an extensive explanation of its physics and design by Eichenbaum and Peter[1]. Concurrent with this work, Buchmiller, DeGrasse, and Wade[12] published detailed design procedures for a modified Watkins[4] velocity-jump gun.

Years before the finishing touches were being made to the exponential-transformer gun, such electron guns were being used in low-noise traveling-wave tubes. In 1954, P. Wakefield[13], who extended the research of Peter and Bloom into product design in the RCA Electron Tube Division, disclosed the development of low-noise tubes of advanced design for 7 db noise figure operation in S-, and C-bands. In 1955, RCA announced the first commercially available low-noise traveling-wave tube, the RCA-6861, which provided a maximum noise figure of 6.5 db in the 2700 to 3500 megacycle frequency band. Very-low-noise S-band amplifiers were thus made available in controlled production to service the growing needs of S-band radar, and to introduce microwave system designers to the traveling-wave tube.

## The Cathode Region and Ultra-Low-Noise Operation

By 1957, scientists working on low-noise traveling-wave tubes were seeking reduction of noise figure in the low-noise gun below the 5 to 6 db values commonly assumed to be minimum at that time. RCA-6861 tubes occasionally produced noise figures of 4.5 db as far back as 1955; 3.5 db noise figure was achieved in 1957 by M. Currie and D. Forster[14] with a backward-wave traveling-wave tube.

Theoretical studies of the cathode region of the low-noise gun produced new and important concepts by 1959. Siegman, Shaw, and Watkins[15] showed that providing a low-velocity drift space between the cathode and the first aperture in the axial path of the electron beam following the cathode, noise figures as low as 1.6 db were possible. Berghammer[16,17] showed that a dense space-charge cushion in the cathode region could give rise to a noise-shielding effect by allowing the electron beam to drift at a small mean velocity (compared to the thermal velocity over a short Debye length) and by making the current density large enough so that the plasma frequency exceeds the operating frequency.

In 1960, as a result these analyses of cathode-region behavior and accumulated operational data, ultra-low-noise traveling-wave tubes established noise figures below 3 db. The target is now 2 db.

Recent analytical studies of the cathode region now indicate the *theoretical possibility* of a zero-db noise-figure traveling-wave tube. Siegman, Watkins, and Hsieh[18,19] and Berghammer and Bloom[20] have shown that velocity spread in the low-electron-velocity region of the beam actually has a beneficial effect on noise. The minimum noise factor NF, in the notation of Haus and Robinson[21], is given by

$$NF = 1 + [S - \pi] N$$

where S and $\pi$ are beam noise powers and N is a function of both temperature and the value of S at the start of the drift region. In this expression, where velocity spread is neglected, S and $\pi$ are constants. However, with velocity spread, S and $\pi$ are variable; velocity spread can cause $\pi$ to increase and S to decrease until S cancels. This effect could result in a zero-db noise figure.

## Noise Figure and Cathode Temperature

The noise figure of a traveling-wave tube is related to the temperature quotient $T_c/T$, where $T_c$ is the cathode temperature in degrees Kelvin and T is room temperature in degrees Kelvin. It is desirable, therefore, to keep the temperature of the cathode as low as possible to reduce noise output.

Beam currents of the order of 100 to 200 microamperes are used in low-noise and ultra-low-noise traveling-wave tubes. The oxide-coated cathodes which provide these beam currents have a diameter of approximately 0.050 inch in S-band tubes. Low emission densities (25 to 50 milliamperes per square centimeter) provide the lowest noise figures; such emission is provided by oxide-coated cathodes at brightness temperatures as low as 600 degrees centigrade (800 degrees is normal for an electron-tube cathode). However, operation at 600 to 650 degrees centigrade insures adequately uniform emission, long life, and reduced intensity of the noise components in the beam emitted from the cathode.

## Noise Figure and Cathode Processing

W. Beam[22] has shown that increased noise figures in low-noise traveling-wave tubes are produced by excess noise velocities caused by cathode-surface nonuniformities. Therefore, the cathode coating must be smooth and of high density. The nickel-cathode base is sprayed with a very wet mixture of triple-carbonate material, binder, and amyl-acetate. The spray jigs are designed to minimize side spray. All parts of the electron guns must be fired and stored in vacuum to prevent contamination and gas formation.

Contamination of the cathode during the activation process can also cause deterioration of noise figure. Accordingly, special techniques are used to activate the oxide-coated cathode. Low tube pressure and low cathode temperature are maintained during every phase of tube degassing. After a long bakeout, the electron beam is drawn only to the first gun aperture and not to or through the helix. This procedure prevents cathode contamination from materials released by electron bombardment.

Such elaborate protection of the cathode actually is essential because the small diameter of low-noise-tube cathodes (0.080 to 0.100 inch for L-band tubes and 0.010 inch for X-band tubes) makes them extremely sensitive to contamination.

## Noise Figure and Magnetic Field

Lowest noise figures have only been obtained when the electron gun is immersed in a strong uniform magnetic field that makes the electron flow essentially parallel or laminar. When the magnetic field is weak, several adverse effects on noise figure occur. As shown by W. Beam[22], reduced intensity of the constraining magnetic field results in transverse mixing of the electrons and an increase in noise. R. Knechtli[23] has shown that at weak magnetic fields, lens effects are introduced in the electron motion from the electron-gun apertures, which produce a further increase in beam noise.

## Noise Figure and RF Coupler and Helix Structures

One of the most important considerations in noise-figure reduction, other than the low-noise electron gun, is the insertion loss of the input circuit of the traveling-wave tube to the point along the helix where the rf wave on the helix has experienced growth. Each unit db of insertion loss in the input circuit represents a direct increase in noise figure by the magnitude of the insertion loss.

For very-low-noise traveling-wave tubes, cavity-type input couplers must be used at the lower microwave frequencies, and waveguide input couplers at frequencies of C-band and above. The insertion loss introduced by such couplers is only a small fraction of a db. Helical couplers, on the other hand, which have insertion loss ranging from 0.5 to 1 db at L-band to 4 to 6 db at X-band may be used only when their higher noise figures can be tolerated.

In the helix region of the traveling-wave tube, losses are reduced by reuse of silver-plated helices and minimum-loss helix-support structures, such as ceramic-rod frames or fluted-glass tubing.

In the output circuit of the traveling-wave tube, circuit losses detract from the tube gain and power levels, but have no effect on noise figure.

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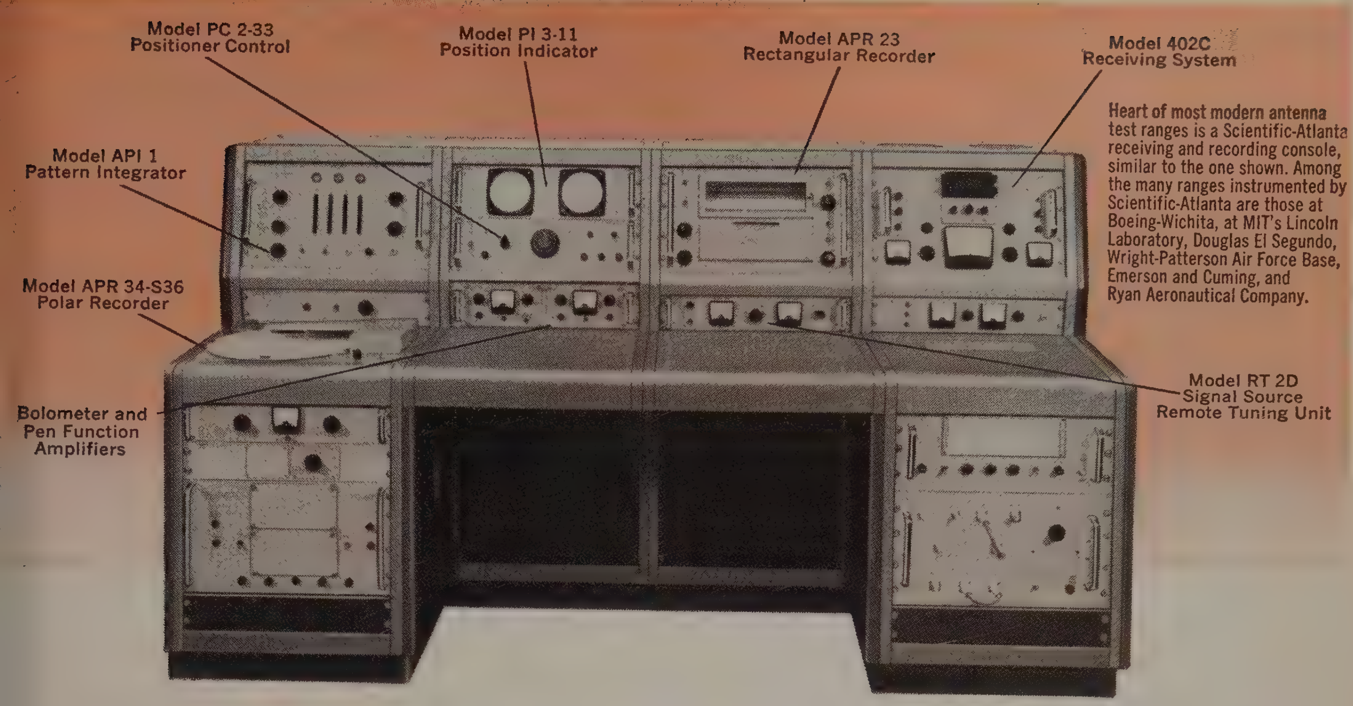
**Part II of Mr. Cuccia's and Mr. Wolkstein's paper will appear in the September issue of *the microwave journal.***



Heart of most modern antenna test ranges is a Scientific-Atlanta receiving and recording console, similar to the one shown. Among the many ranges instrumented by Scientific-Atlanta are those at Boeing-Wichita, at MIT's Lincoln Laboratory, Douglas El Segundo, Wright-Patterson Air Force Base, Emerson and Cuming, and Ryan Aeronautical Company.

# ONE SOURCE
# For Complete Antenna Instrumentation Systems

## *Recording, Receiving, Transmitting and Control Equipment, Antenna Positioners, Microwave Components, and Recorder Supplies*

**PATTERN RECORDERS**—Two basic pattern recorders are available: the Series APR 20 Rectangular, and Series APR 30 Polar. They can be combined to form the popular APR 20/30 Polar-Rectangular Recorder. Pen responses include logarithmic, linear, and square root.

Features include servo control with tachometer feedback, a noise compression circuit, an electric pen lift, and a three-axis synchro input selector. The rectangular recorder has an automatic chart-cycle advance, illuminated chart, three chart scale expansions with forward-reverse, and chart position control. The polar recorder features a recording diameter of 7 and 13 inches, a turntable slip-clutch, pen standby and load switch, calibrated turntable, and chart center light.

**WIDE RANGE RECEIVING SYSTEM**—A double conversion superheterodyne receiver, the Scientific-Atlanta Series 402 covers the range from below 30 mc to more than 100 kmc.

Features include a sensitive AFC circuit which prevents the receiver from losing track during transmitter frequency drift. One coaxial cable eliminates costly lossy wave guides and rotary joints. Antennas can be located up to 75 feet away with negligible loss in sensitivity, or more than 200 feet away with low loss cables. Reception of cw signals from simple sources eliminates need for precise modulation.

Excellent employment opportunities exist for electronic, microwave, and mechanical engineers.

Modification P-4 adds 20 db to the normal 40 db dynamic range providing 1 db linearity over a full 60 db dynamic range. Modification Z adds a precision IF attenuator and VTVM appreciably reducing the number of components and instruments required for level, gain, and isolation measurements.

**ANTENNA POSITIONERS**—Scientific-Atlanta offers medium and heavy duty azimuth and multi-axis antenna positioners. Standard models range from the PMA-3 medium duty azimuth positioner designed for a maximum vertical load of 200 pounds with a maximum bending moment of 200 foot pounds to the large PAEA 29 H azimuth over elevation over azimuth for vertical loads of 15 tons and a bending moment of 30,000 foot pounds.

Features include use of Kaydon four-point contact bearings which minimize sliding friction, weather and dust proof design, and 1:1 and 36:1 speed synchros for each axis of rotation. Slip rings, rotary joints, and limit switches can be provided in any axis of any positioner.

**MICROWAVE COMPONENTS**—Scientific-Atlanta also offers a coaxial rotary joint for dc to 16 kmc at speeds up to 2000 rpm, a series of coax to waveguide adaptors, standard gain horns, crystal mixers, transmitting antennas, polarization positioners, model range towers and recorder supplies.

### WRITE FOR OUR NEW CATALOG

Ask your Scientific-Atlanta engineering representative for a copy of our new catalog or write directly to the factory.

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ATLANTA, INC.**
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See Us at WESCON — Booth 3522

# New Products

### COOPERTRONIX INTRODUCES BROAD BAND SQUARE WAVE GENERATOR

Coopertronix, Inc., Palo Alto, Cal., announces the model 104 square wave generator with a frequency range of 850 to 1150 cps and a 0 - 60 volt peak to peak, direct coupled output.

The model 104 may be utilized to modulate backward wave oscillators, traveling-wave tubes, and klystrons. Other frequency ranges are available.

**Circle Reader Service Card 101**

*—mwj—*

### MINIATURE SSB CRYSTAL FILTER OFFERED BY HUGHES

The Industrial Systems Division, Hughes Aircraft Co., Los Angeles, Cal., has developed a set of lower and upper sideband crystal filters with three - 45 db carrier rejection in 200 cps in a single package of 11 cubic inches.

The filter set was designed at a carrier frequency of five Mc with passband width of 3.2 kc on each side (can be narrower or wider). In the past such a sharp carrier rejection was feasible only at about one-third of this frequency and required a total volume of about 17 cubic inches. Low ripple and excellent stability over wide temperature ranges are reported.

**Circle Reader Service Card 102**

*—mwj—*

### MICROWAVE PULSE GENERATOR OFFERED BY HALLICRAFTERS

The MPG-3 Microwave Pulse Generator which produces nanosecond pulses at gigacycle frequencies from conventional radio frequency signal generators has been introduced by Hallicrafters Co., Chicago, Ill. The MPG-3 can also serve as a self-contained wideband traveling-wave-tube amplifier or as a serrodyned amplifier for frequency translation.

The MPG-3 is available in six bands — UHF, L, S, C, X, and KU — covering the microwave spectrum from 0.5 - 18 gc/s. Both pulse widths and pulse repetition rates can be precisely adjusted. Pulse widths range from 0.03 - 500 microseconds and pulse repetition rates can be varied from 2 - 50,000 pulses per second. Power output is 10 milliwatts.

Heart of the MPG-3 unit is a periodically focused traveling-wave-tube amplifier with special circuits for pulse modulating the externally generated microwave signals using only one TWT instead of two as has been necessary for earlier nanosecond microwave pulse generators.

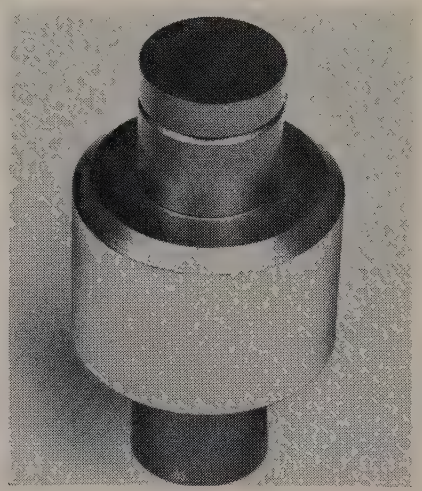
The MPG-3 microwave pulse generator is available initially for X-band use (8 to 12 gc/s) packaged to military or commercial specifications, delivery 45 days after receipt of order. Prices on request.

**Circle Reader Service Card 103**

*—mwj—*

### MICROWAVE ASSOCIATES INTRODUCES HIGH "Q" SILICON POWER VARACTORS

A series of 55 new high "Q" silicon power varactors with a wide variety of breakdown voltage values from 6 volts through 120 volts has been introduced by Microwave Associates Inc., Burlington, Mass.



Major uses for the diodes are in microwave communications transmitters, radars, beacon transponders, and other special test equipment functions.

The diodes (MA-4351A-G through MA-4358A-F) provide unprecedented high efficiency harmonic generation and are recommended for applications in the 1 Mc - 40,000 Mc region. The new subminiature "pill" case featuring axial prongs for convenient mounting in strip-transmission-line or other circuits, represents a novel case style with unique advantages for the user.

One of the prongs may be removed so that the case can be mounted upon tapped posts. This is especially convenient for mounting within miniature cavities as in microwave harmonic generators and cavity tuning applications.

In addition to harmonic generation at power input values in excess of one watt, the diodes are very efficient sideband modulators through 40 kMc and also as low-loss RF switches, limiters, and levelers.

**Circle Reader Service Card 104**

*—mwj—*

### DESIGN AID HELPS SOLVE ELECTRONIC PACKAGING PROBLEMS

Sanders Associates, Inc., Nashua, N. H., has introduced a convenient design aid for solving electronic packaging problems.

A flat perforated card stamped in the form of Sanders Subminiature Minicube® Blower is quickly hand-folded into an actual size cardboard mock-up that can be placed in a breadboard, package mock-up or actual chassis to determine the best location for the blower itself or associated components.

By this device, engineers can readily demonstrate for themselves how little room this one cubic inch blower takes to solve cooling, de-fogging and circulating problems in electronic, photographic and similar equipment. Sanders Subminiature Minicube® Blower lowers ambient temperature in miniaturized airborne equipment, and eliminates hot spots around klystrons and other electronic tubes and devices.

Each Subminiature Minicube® Blower is ruggedly constructed to withstand acceleration, shock and vibration requirements of military specifications for missile and aircraft applications.

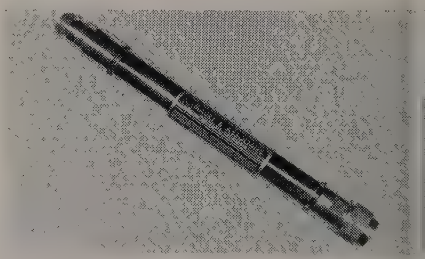
**Circle Reader Service Card 105**

*—mwj—*

### TUNED MICROWAVE ATTENUATORS DEVELOPED

Maury & Associates, Montclair, Cal., has introduced a new series of tuned microwave attenuators. The new series designated Series AT, incorporates new matching techniques developed by M&A which provides an extremely well matched precision attenuator for systems applications.

The attenuators are fixed tuned to a desired center frequency and are available from one to 4 kMc with attenuation values from one to 20 db. The VSWR limits are 1.05 maximum at the center frequency and 1.10 for a ±10 per cent bandwidth. Attenuation accuracy is ±0.3 db for one through 10 db and ±0.5 db from 11 to 20 db. They handle one watt cw, one kilowatt peak with a nominal impedance of 50 ohms.



The attenuators are bi-directional, negligibly affected by temperature or humidity changes and are ruggedized. The units are obtainable with type N or C connectors and are supplied with individual calibration information.

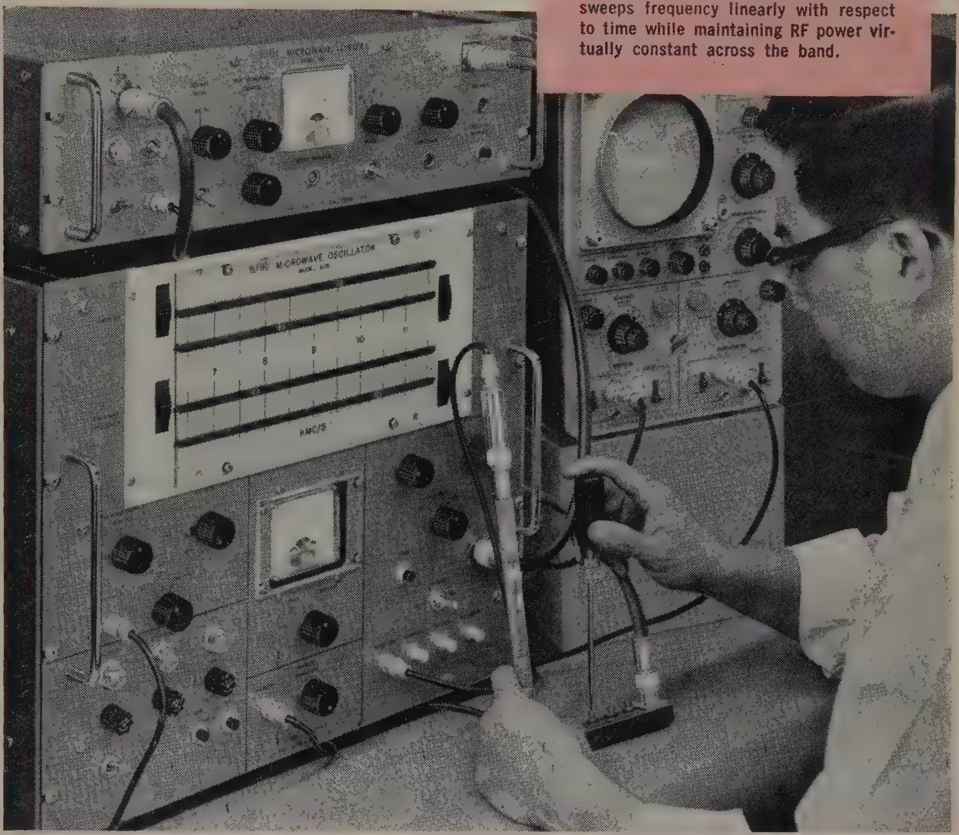
**Circle Reader Service Card 106**

*—mwj—*

(Continued on page 94)

# ALFRED ELECTRONICS

** First in quality broadband microwave instrumentation*



Testing insertion characteristics of X-band filter with Alfred Swept Generator which consists of Alfred Microwave Oscillator and Alfred Microwave Leveler. This combination electronically sweeps frequency linearly with respect to time while maintaining RF power virtually constant across the band.

## MICROWAVE SWEEP GENERATORS

Still the industry's most advanced oscillators. Series 620 single band models and Model 605 use convenient plug-in generator heads covering 1-26.5 kmc. Models 6001B-6004C provide 1 watt output, electronically swept or stable single frequency, 1-12 kmc.

Features include built-in leveler and narrow band symmetrical sweep, adjustable frequency markers, and Quick Look readout. Drift, less than ±.02% per hour; residual FM, less than ±.0025% peak.

These units save valuable engineering time by providing constant RF power input to microwave tubes and other components under test. With constant input, variations in output indicate directly component transfer characteristics. Microwave properties are examined over continuous spectrum, assuring accuracy during broad or narrow band testing. Prices: Model 620 series, $2,890-3,340; Model 605, $1,750; Generator Heads, $1,500-1,990; Model 6001B-6004C, $7,250-8,690.

## MICROWAVE LEVELERS

Ideal instruments for maintaining constant power output (±1 db) with long term stability. CW or square wave modulation. Fast response, very high gain assure flat RF output from BWO's. Also available: Model 700 leveler amplifier, which may be used with external RF components. Prices: Microwave Levelers, $875-990; Model 700, $575.

## MICROWAVE AMPLIFIERS

Alfred manufactures microwave amplifiers for virtually every requirement — general purpose, medium power, high gain, and low to medium noise figure. All models feature low spurious modulation and stable operation. General purpose amplifiers provide 30 db gain and 10 mw power output with 25 db noise figure. Medium power models offer power up to 10 watts. High power amplifiers provide up to 1 Kw pulse power. Low noise amplifiers provide noise figure from 6 to 15 db at frequencies from .5 to 12 kmc.

In addition to standard amplifiers, Alfred offers periodic or permanent magnet focused amplifiers where light weight and low input power is required as well as amplifiers designed specifically for phase modulation. Prices: General purpose amplifiers, $1,490-1,690; Medium power amplifiers, $1,550-3,590; Low noise amplifiers, $3,150-4,990.

## POWER SUPPLIES

Alfred furnishes four basic types of power supplies. Model 250 Traveling Wave Tube Supply operates low and moderate power traveling wave amplifier and oscillator tubes. This instrument provides all normal sources — helix, collector, four separate anodes, grid, heater, solenoid and blower — from one compact unit.

Microwave Power Supplies Model 252, with the unregulated and regulated solenoid supplies Model 253 and 254, operate all presently known low and medium noise figure TW tubes. Model 252 furnishes electrode and heater power for permanent magnet focused TW tubes. Electromagnet focused TW tubes require in addition either Model 253 or 254 solenoid supply. Alfred's Sweeping Power Supplies serve as general purpose sources for either electronically swept or fixed frequency operation of voltage tuned magnetrons, BWO's and similar microwave tubes. Alfred's floating high voltage supplies provide extremely stable and highly regulated DC voltages, featuring wide voltage and current ranges, very small ripple and accurate voltage adjustment. Prices: Model 250, $1,990; Models 252, $890; 253, $300; 254, $400; Sweeping Power Supplies, $1,650-1,690; High Voltage Supplies, $690-1,090.

*Free catalog available. Write to:*

## ALFRED ELECTRONICS

**897 Commercial Street • Palo Alto, California**
**Phone: DAvenport 6-6496**

See us at
WESCON
Booth 1412

Circle Reader Service Card 53

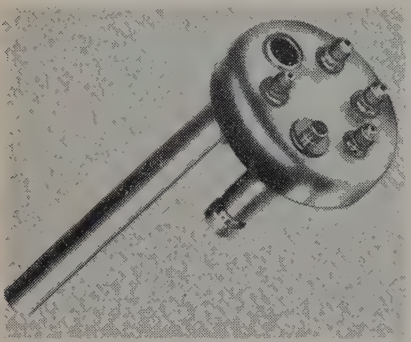
## New Products

(*Continued from page 92*)

### MULTI-TERMINAL BASES BUILT FOR TRAVELING-WAVE TUBES

Ceramics International Corp., Mahwah, N. J., specialists in mass production of quality ceramic-to-metal products, has enlarged its production of multi-terminal bases for traveling wave tubes.

The assembly consists of a nickel cup supporting ceramic-to-metal tubular feed throughs, together with an integral ceramic-to-metal input adaptor and copper evacuation tube. The number of feed throughs varies from four to eight depending on the electron tube involved. The number of simultaneous braze joints made with copper or alloys of gold varies up to 19.



The ceramic-to-metal tube base components are metalized by a special method which substantially reduces subsequent production failures in the manufacture of the end product. A major factor in the improved results is CI's contamination-free production facilities, where all components are handled with gloves and brazing is accomplished on ceramic jigs in such a way that the electrical characteristics of the end product closely match those of the ceramic used. This method enables the engineer to match his calculated final specifications more precisely than was ever before possible.

The tube bases are rugged and withstand repeated welding operations and a bakeout in air at 700°C for 72 hours without leaking.

**Circle Reader Service Card 107**

*— m w j —*

### VOLTAGE MONITORS AVAILABLE FROM ALTRON

UHF Coaxial Thermo-Converters — a complete line of high-frequency voltage monitors combining reliability and precision are available for the measurement of current and voltage from DC to 400 Mc from Altron Electronics Co., Ridley Park, Pa.

One of the great advantages of these high-frequency voltage monitors is their complete electrical isolation of the input and output circuits. Full scale voltage ranges are from 0.1 - 101.0 volts.

The models UF7 series of UHF thermo-converters have been specifically designed for rugged remote monitoring and/or recording of RF and AF voltages and currents from DC to 400 Mc.

**Circle Reader Service Card 108**

*— m w j —*

### HUGHES DEVELOPS ALL SOLID STATE X-BAND LIMITER

Development of an X-band all solid state microwave power limiter has been announced jointly by the Navy Bureau of Ships and Hughes Aircraft Co., Culver City, Cal.

The limiter, which can serve as a replacement for TR tubes presently used in radar systems, was developed under a Navy-sponsored research effort, according to Dr. Howard T. Ozaki, manager of the microwave components department in the Hughes aerospace research and development division.

Engineers exploited the nonlinear properties of both ferrites and diodes to construct a combination ferrite-diode power limiter which is satisfactory for use in radar systems as a mixer crystal protector.

Ozaki said that the advantages of the device are completely passive operation; instantaneous recovery time; extremely long life; and excellent reliability and protection at high power levels.

**Circle Reader Service Card 109**

*— m w j —*

(*Continued on page 97*)

STOP LOOKING — IT'S HERE!

VOL. (14 in³) WT. (12 oz.)
MODEL P-20H **

THE MICROWAVE CAVITY FOR S BAND TELEMETRY APPLICATIONS, WITH A TANK CIRCUIT EFFICIENCY OF 35% IN AMPLIFIER OPERATION.

FEATURES

Tank circuit efficiency of 35% in amplifier operation

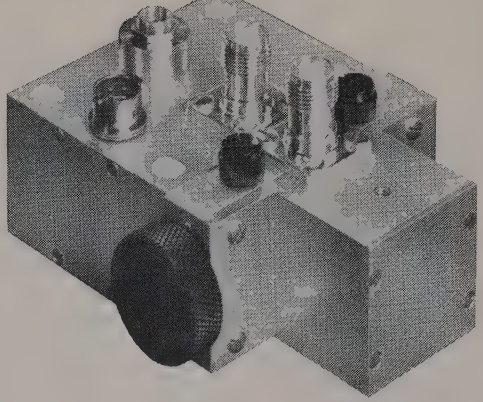
Smooth low back lash tuning

Lightweight

Heatsink design

Derating of components

All electrical connections are on top surface.



SPECIFICATIONS

UTILIZING 6771 CERAMIC-METAL PLANAR TRIODES

| Model | Description | Typical Gain Between 2075 and 2325 LOW POWER db | LOW POWER Output | HIGH POWER db | HIGH POWER Output |
|---|---|---|---|---|---|
| P-20H | Power amplifier | 14 | 1.2W | 10 | 2 W |
| x2-20H | Frequency doubler | 6 | .8W | 4.5 | 1.5 W |
| x3-20H | Frequency tripler | 1.5 | .3W | 1 | .75W |

PLATE POWER REQUIREMENTS: 250 V @ .025a FOR ALL UNITS.
HEATER.SUPPLY IS 6.3 V @ .6a FOR ALL UNITS

PRICE: $895.00
F.O.B. PASADENA, CALIFORNIA
For quantity prices contact RESDEL direct

Immediate openings available for senior microwave engineers.

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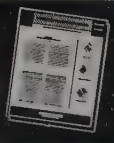

Circle Reader Service Card 54

**40-DAY WONDER...** TRG produced and delivered this order of A and V band millimeter wave devices in just 40 days. To save you the trouble of counting we'll itemize: 24 ferrite devices, 3 antennas, 24 circular wave guide components, and 21 pieces of test bench equipment – 72 high precision components in all. In this highly specialized field, such special delivery is not the kind you find on postage stamps. It is the result of TRG's unique capabilities in the millimeter wave field. Today, there is only one source for a complete line of millimeter wave components of all types covering the entire 26.5 – 140 KMC region. That source is TRG. Whatever your problem – a component, or complete systems development . . . TRG has more of everything it takes, including experience, to place the answers right in the palm of your hand. Write for Catalog 260A today.

**TECHNICAL RESEARCH GROUP** 9 Union Square, Somerville, Mass.

**TRG tunable Crystal Holder Model V1000.** TRG is the only source for this crystal holder, used with the Philco IN2792 mixer diode for 70 KMC operation. The reversible polarity of the Philco IN2792 permits use on either side of a balanced mixer. Typical overall NF, 13db. Integral tuning adjustment matches all crystals to <2:1 VSWR. VSWR <1.5 for selected crystals. RG/98/U waveguide input pressurized to 30 PSI.

**TRG MILLIMETER WAVE COMPONENTS (PARTIAL LISTING)**

| FREQUENCY RANGE — KMC | A-band 26.5–40 | V-band 50–75 | E-band 60–90 | F-band 90–140 | TYPICAL PERFORMANCE FOR A, V, E AND F BANDS | REMARKS |
|---|---|---|---|---|---|---|
| Isolator | A110 | V110 | E110 | F110 | VSWR 1.25 — Loss .7db — Isolation 17db min., 25db at center | Bandwidth: 6% A-band, 3% V and E-band. Low power Faraday rotation type isolator |
| Mode Transition | A330 | V330 | E330 | F330 | 5% Band — VSWR 1.25 — Loss .3db — 18db mode purity | $TE_{10}$ rectangular guide to $TE_{01}$ circular guide |
| Mode Filter | A340 | V340 | E340 | F340 | VSWR 1.2 — Loss: $TE_{01}$ mode .3db, $TE_{11}$ mode 5db | Helical waveguide surrounded with lossy material |
| 90° Bend | A360 | V360 | E360 | F360 | VSWR 1.15 — Loss .3db | Corrugated circular waveguide — $TE_{01}$ mode |
| Uncalibrated Attenuator | A520 | V520 | E520 | F520 | VSWR 1.2 — Attenuation .2db to 25db | Resistance card inserted in waveguide |
| Gain Standard Horns | A890 | V890 | E890 | F890 | | Nominal Gain 25db—Calibration to ±0.3db supplied (based on NRL design) |

TRG INC., ANTENNA & MICROWAVE DEPT., 9 UNION SQUARE, SOMERVILLE, MASS. PHONE: MOnument 6-8680

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## C TYPE MAGNETS in a wide range of sizes to meet your design needs in ★Transverse Field Isolators ★ Differential Phase Shifters ★ Duplexers

Arnold C-type Alnico Magnets are available in a wide selection of gap densities ranging from 1,000 to over 7,500 gausses. There are six different basic configurations with a wide range of stock sizes in each group.

The over-all size and gap density requirements of many prototype designs can be met with stock sizes of Arnold C Magnets, or readily supplied in production quantities.

When used in transverse field isolators, Arnold C Magnets supply the magnetizing field to bias the ferrite into the region of resonance, thus preventing interaction between microwave networks and isolating the receiver from the transmitter. These magnets are also used in differential phase shifters and duplexers, and Arnold is prepared to design and supply tubular magnets to provide axial fields in circular wave guides.

A feature of all Arnold C Magnets is the excellent field uniformity along the length of the magnet. Versatility in design may be realized by using multiple lengths of the same size magnet stacked to accomplish the needs of your magnetic structure.

Let us work with you on any requirement for permanent magnets, tape cores or powder cores. ● For information on Arnold C Magnets, write for Bulletin PM-115. Address *The Arnold Engineering Company, Marengo, Illinois.*

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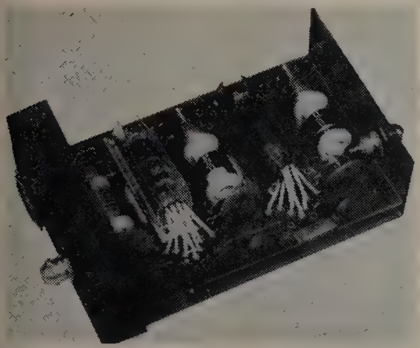
**ARNOLD**

**SPECIALISTS in MAGNETIC MATERIALS**

BRANCH OFFICES and REPRESENTATIVES in PRINCIPAL CITIES
*Find them FAST in the YELLOW PAGES*

*(Continued from page 94)*

### MODULAR IF PREAMPLIFIERS MADE AVAILABLE BY ORION



A group of modular IF preamplifiers, designed specifically to provide the optimum in low noise operation is now made available by Orion Electronic Corp., Tuckahoe, N. Y. The preamplifiers, bearing the designation of Series H, furnish the low noise operation so essential in designing any receiving system for optimum sensitivity.

Any increase in sensitivity or decrease in noise figure, decreases the requirements of the transmitter. Because of the input matching requirement for low noise operation, Series H modular IF preamplifiers can be furnished with either a balanced or unbalanced input.

The output impedance of all amplifiers in the Orion Series H is 50 ohms. The tube units—either miniature or subminiature — operate from −50°C - +85°C, whereas the germanium transistor preamplifiers have a temperature capability of −20°C - +50°C. Silicon preamplifiers can also be supplied for high temperature operation but at an increased noise figure.

Orion Series H modular preamplifiers are small in size. The miniature tube types measure 5¼ inches x 2¼ inches x 3 inches; both the subminiature tube and transistorized versions measure 1¼ inches x 2¼ inches x 3 inches.

Price is $200-250 per unit depending on type.

**Circle Reader Service Card 110**

*—mwj—*

### MICROWAVE DEVELOPMENT OFFERS SHORT SLOT HYBRID

Model 15HS 12 (RG98/U) standard sidewall short slot hybrid, an investment casting available in beryllium copper has been introduced by Microwave Development Laboratories Inc., Natick, Mass.

The short slot hybrid, measuring 0.500 inch long, has a 0.040 inch common wall, and covers the frequency range 68.0 - 72.0 gc. Other electrical specifications include: 0.25 db maximum unbalance, and 30.0 db minimum isolation.

A new catalog (HS61) listing more than 100 models including the above is available.

**Circle Reader Service Card 111**

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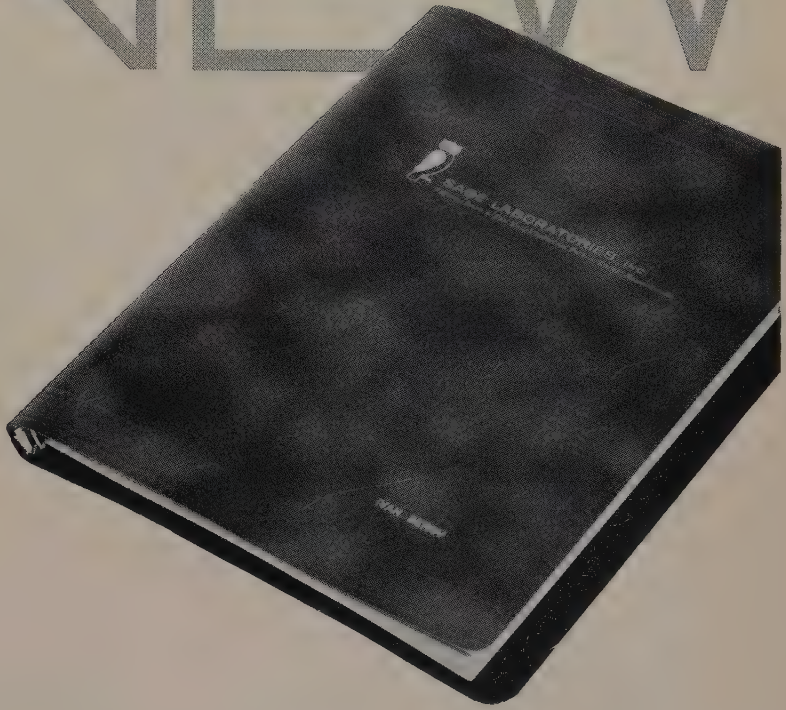
*(Continued on page 98)*

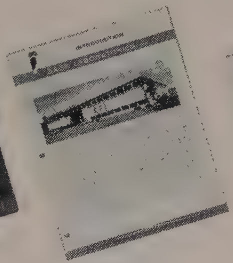


NEW

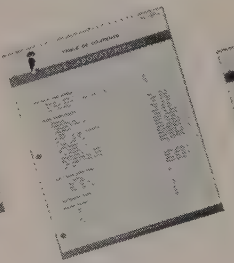
CATALOG OF SAGE COMPONENTS

Natick, Massachusetts . . . August 10, 1961 . . . Sage Laboratories, Inc. announces the publication of a new microwave components catalog developed specifically for belabored engineers and purchasing agents . . . all data is factual, clear, concise, and complete . . . the initial edition includes technical discussions, product sections and supporting literature . . . a flexible, personalized cover provides for easy inclusion of additional material as published . . . qualified persons may obtain a copy by forwarding name, title and address on company letterhead.

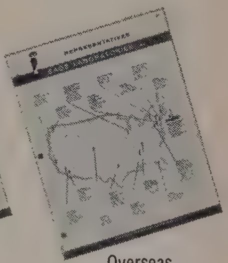
Recipient's name



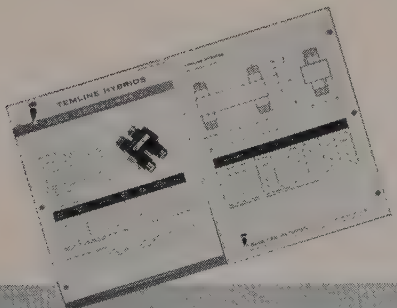
History and Facilities Synopsis



Coaxial and Waveguide Components



Overseas Cable Address.
WARWICK — BOSTON



Section 750 — TEMLINE HYBRIDS — A typical data sheet including product description, application, complete electrical and mechanical specifications and prices.

SAGE LABORATORIES, INC.
3 HURON DRIVE • EAST NATICK INDUSTRIAL PARK • NATICK, MASSACHUSETTS •

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*Lincoln Laboratory is supplementing its staff. The Laboratory is engaged in basic air defense research for the space age. This expanding program is a natural outgrowth of our advanced research and development in the fields of Radio Physics, Radar, Systems Studies, Satellite Surveillance, Computer Technology and Solid State Physics. Senior scientists are invited to join the Laboratory in solving urgent problems of importance to the defense of the United States.*

*The Laboratory is seeking qualified specialists in:*

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- A more complete description of the Laboratory's work will be sent to you upon request.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

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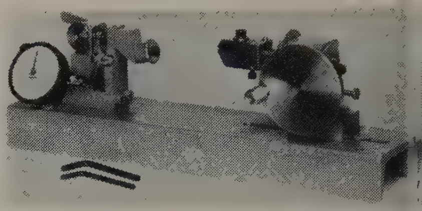
LEXINGTON 73, MASSACHUSETTS

## New Products

*(Continued from page 97)*

### HUGHES DIVISION OFFERS WELD STRENGTH TESTERS



The addition of weld joint tensile testers to its line of electronic welding equipment has been announced by the Vacuum Tube Products Division of Hughes Aircraft Co., Oceanside, Cal. The portable units find application in the development of weld schedules used in high density electronic component packaging as well as in statistical quality control of production welding.

The units are available in two models: the VTA-46, having a testing range of 0 - 50 pounds, and the VTA-47 with a 0 - 100 pound range. Both models feature a load indicator which holds the maximum specimen pull until reset. A one to one mechanical adjustment of the load jaws makes possible quick set-ups, but actual loading is applied through a 100 - 1 reduction wheel.

Other features of the units are a jeweled meter movement, interchangeable jaws and anti back-lash provisions to prevent surge readings at the breaking point.

Price of the units is $325.00 each. Delivery can be made from stock.

**Circle Reader Service Card 112**

*—mwj—*

### SCANWELL LABORATORIES OFFERS LOW PASS FILTER

Scanwell Laboratories, Inc., Springfield, Va., has announced the development of a new adjustable low pass filter.

The filter, model 102, features a fundamental frequency of 225-400 Mc/sec; a fundamental power rating of 150 watts, CW, continuous; a fundamental attenuation of 0.6 db maximum and a harmonic attenuation of 70 db minimum for all harmonics to 4600 Mc/sec.

Other characteristics of the new model include a VSWR of less than 1.5, an impedance of 50 ohms and type N jack connectors.

**Circle Reader Service Card 113**

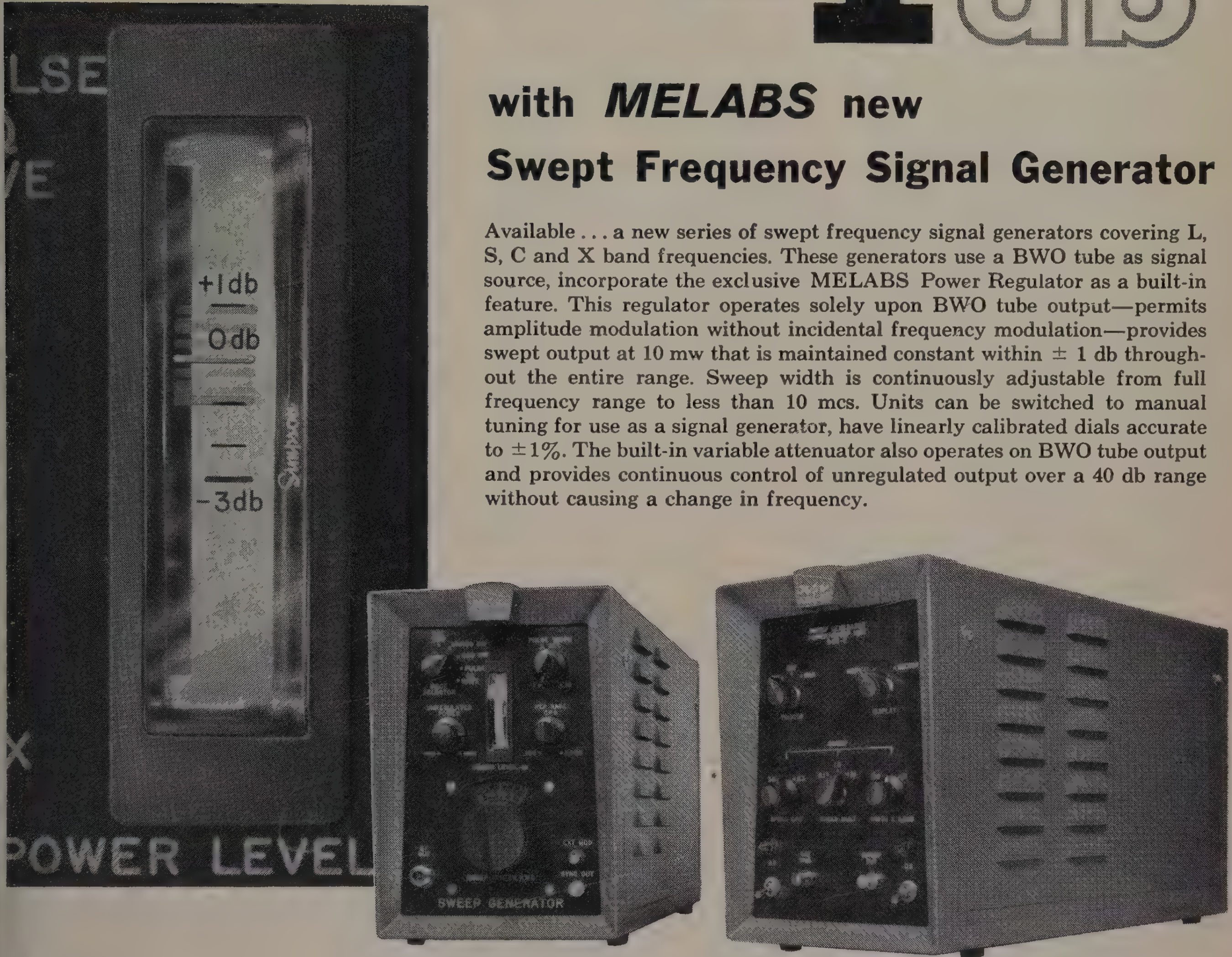
*—mwj—*

*(Continued on page 100)*

# ...OUTPUT CONSTANT ±1db

## with *MELABS* new Swept Frequency Signal Generator

Available . . . a new series of swept frequency signal generators covering L, S, C and X band frequencies. These generators use a BWO tube as signal source, incorporate the exclusive MELABS Power Regulator as a built-in feature. This regulator operates solely upon BWO tube output—permits amplitude modulation without incidental frequency modulation—provides swept output at 10 mw that is maintained constant within ± 1 db throughout the entire range. Sweep width is continuously adjustable from full frequency range to less than 10 mcs. Units can be switched to manual tuning for use as a signal generator, have linearly calibrated dials accurate to ±1%. The built-in variable attenuator also operates on BWO tube output and provides continuous control of unregulated output over a 40 db range without causing a change in frequency.



The generator "package" is broken down into two units to reduce weight, facilitate easy carrying by one man. The same power supply/sweep unit can be used with any of the MELABS electronically tuned generators.

The many built-in features of these generators tend to reduce materially the amount of external equipment necessary for accurate visual presentation of equipment characteristics. Operation is simple, straightforward.

### SPECIFICATIONS (Similar for all units)

**POWER OUTPUT:** Regulated, 10 mw ±1 db. Unregulated, continuously adjustable over 40 db range.

**INTERNAL MODULATION:** For regulated power: **Pulse,** 1-10 usec. width, prf, 100-5000 cps. **Square wave,** repetition rate 1000 cps with ±10% front panel adjustment.

**EXTERNAL MODULATION:** Any type, unregulated only.

**SWEEP:** .03 to 30 cps with sweep widths continuously adjustable to 100% of Frequency Range.

**DIMENSIONS:** 11"H, 8"W, 21¼"D, each unit.

**WEIGHT:** **Power supply,** approx. 65 lbs. **RF heads,** approx. 35 lbs.

**AVAILABLE MODELS: RF** heads,
Model **SGL-2,** 1-2 kmc.....2600.00
Model **SGS-2,** 2-4 kmc.....2300.00
Model **SGC-2,** 4-8 kmc.....2400.00
Model **SGX-2,** 8-12 kmc....2600.00

**POWER SUPPLY/SWEEP UNIT** (required for each RF head)
Model **SGO-2**..........900.00
will operate with any of the listed RF heads.

DATA AND PRICES SUBJECT TO CHANGE WITHOUT NOTICE. PRICES F.O.B. FACTORY.

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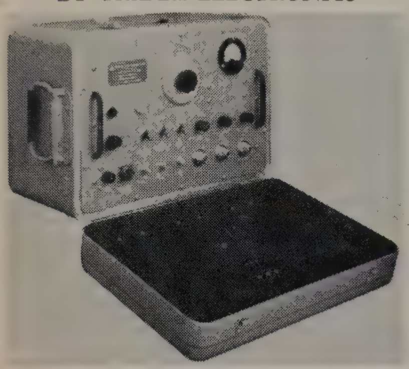
*3300 Hillview Avenue, Palo Alto, California Dept. A-3 DA 6-9500 Area Code 415*

Circle Reader Service Card 58

(Continued from page 98)

### SIGNAL GENERATOR DEVELOPED BY TRIDEA ELECTRONICS



The design and manufacture of a new high stability signal generator available with center frequencies from below 100 Mc to 3000 Mc is announced by Tridea Electronics, Inc., South Pasadena, Cal. The Tridea Model 190 high stability signal generator incorporates advanced design features with unusual capability for phase-lock receiver testing.

The instrument provides AM, FM, phase modulation, or CW output signals with continuous control of the rf output level between —30 dbm and —130 dbm. Lower signal levels are available with external attenuators.

Of special importance is the high frequency stability of the signal generator under extreme environmental conditions and the low rf leakage level. The leakage level is less than —145 dbm measured at a distance of 2 feet from the signal generator.

The unit is mounted in a water-tight portable case, operates from 115V single-phase 60-cps power, and is capable of remote operation.

**Circle Reader Service Card 114**

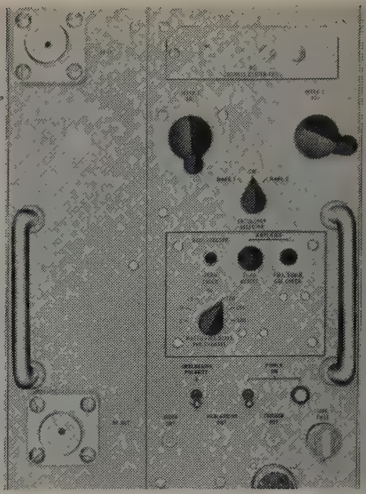
*—mwj—*

### INCREMENTAL MICROWAVE POWER SPECTRUM ANALYZER OFFERED

An incremental power spectrum analyzer has been developed by Hallicrafters Co., Chicago, Ill., to provide direct reading measurements of RF power and frequency with laboratory accuracy under operational conditions for stationary, mobile, airborne or shipboard application. Using sampling techniques, the instrument provides a continuous display of microwave signal power distribution with an accuracy formerly obtainable only with point-to-point measurements.

The first model of the incremental power spectrum analyzer offered commercially covers the S-band spectrum from 2400 to 3650 megacycles per second in 125 narrow-band increments of 10 megacycles each. For complete coverage of the band, the 10-Mc/s channels overlap at the half-power (3db) points.

The average output of each channel is sampled in sequence 30 times a second, and all 125 incremental measurements are displayed on an oscilloscope as closely spaced discrete points. Alternatively, the sampled measurements can be fed directly to recording or automatic data logging equipment.



The analyzer consists of 125 fixed-tuned narrow-band crystal video receivers whose outputs are integrated to produce dc voltages proportional to the time average of the RF power in the channels. The detector outputs are sampled sequentially by a high speed commutator and applied to the vertical deflection amplifier of an oscilloscope. The oscilloscope sweep is synchronized with the commutator to generate a dot pattern display on the CRT.

**Circle Reader Service Card 115**

*—mwj—*

(Continued on page 102)

PARABOLIC ANTENNAS
From 4 inches to 16 feet
MECATORN® POWERSPUN
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FOR FURTHER INFORMATION —
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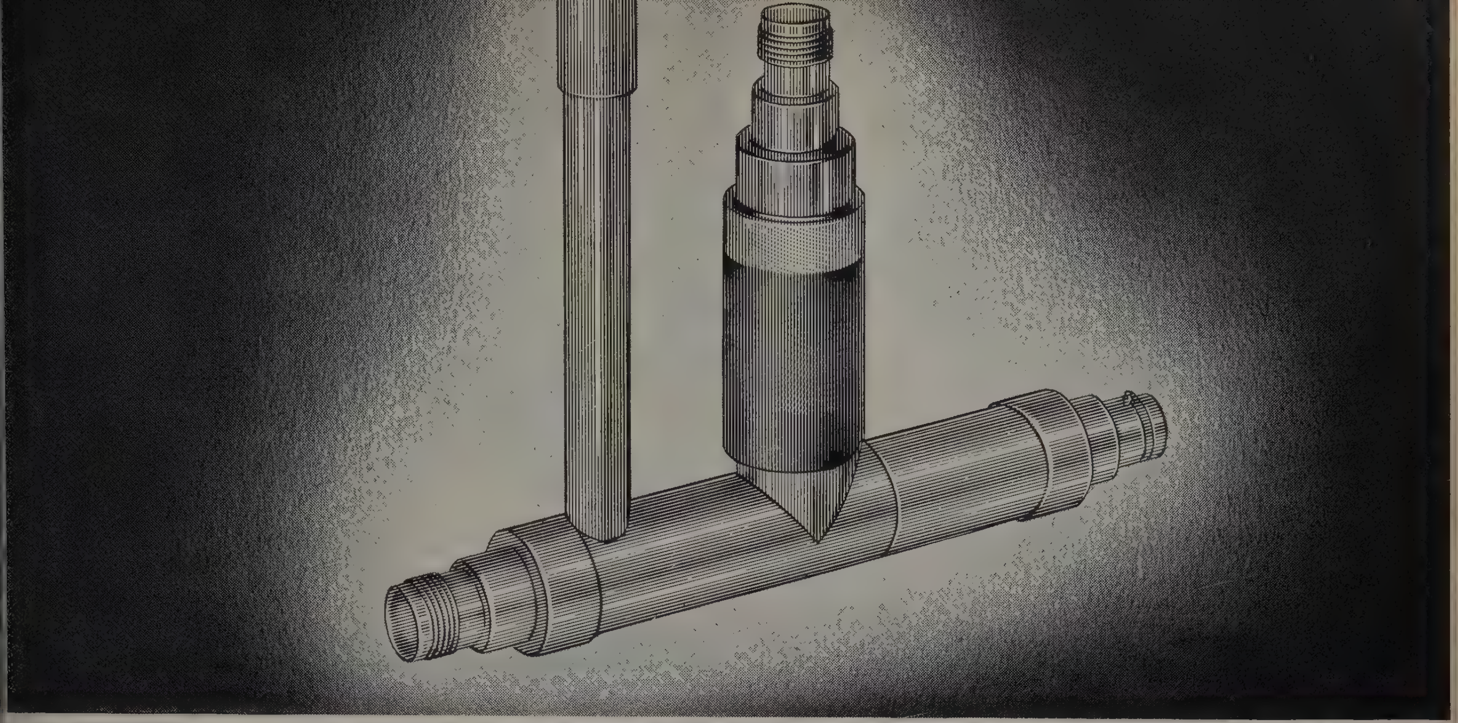

# NEW

# CRYSTAL MIXERS

## FOR USE AS LABORATORY INSTRUMENTS OR IN AIRBORNE SYSTEMS.

A COMPLETE LINE OF CRYSTAL MIXERS IS NOW AVAILABLE FOR IMMEDIATE DELIVERY. THE XR SERIES, FIXED TUNED UNITS, ARE AVAILABLE IN STANDARD FREQUENCIES FROM 225 TO 6000 MC. THE XS SERIES ARE UNTUNED UNITS EACH COVERING THE ENTIRE FREQUENCY RANGE FROM 10 TO 6000 MC. THE XT SERIES ARE TUNABLE UNITS, ONE COVERS FREQUENCIES FROM 300 TO 2000 MC, THE OTHER COVERS FREQUENCIES FROM 1000 TO 6000 MC. FEATURING HIGH CONVERSION EFFICIENCY AND LOW NOISE OUTPUT, THESE CRYSTAL MIXERS ARE MINIATURIZED, RUGGED AND LIGHTWEIGHT. WRITE FOR CATALOG 10A.

"See us at booth 4306 at WESCON"

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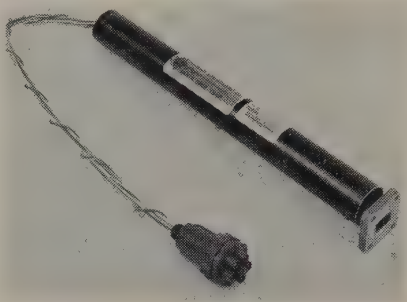
Circle Reader Service Card 60

*(Continued from page 100)*

## EXTENDED-RANGE BACKWARD WAVE OSCILLATOR CONSTRUCTED



A high-performance backward wave oscillator, providing between 10 and 20 milliwatts of power throughout its range of 15-22 kilomegacycles, has been introduced by Stewart Engineering Co., Santa Cruz, Cal. The new tube, model OD 15-22, offers wide-range electronic tunability, a smooth curve of power output vs. frequency, and highly uniform, reproducible characteristics.

The new BWO design is the latest in a series of 12 Stewart backward wave oscillators in the range from one through 22 kMc. It is a hard glass and metal, helix-type high vacuum tube, enclosed in a cylindrical capsule and provided with a waveguide flange. The power input cable terminates in a type PM6P hooded plug.

Price of the new Stewart tube is approximately $1,250, depending upon quantity requirements. Delivery of 30 days ca normally be obtained.

**Circle Reader Service Card 116**

—*m w j*—

## ANTENNA RANGE SIMULATOR DEVELOPED BY MELPAR

Melpar Inc., Falls Church, Va., has developed an antenna-range simulator fo flight-line testing X-Band aircraft rada at very close range.

Called the Model 100 Simulator, th device is compact, transportable and relatively inexpensive. It can simulate fixe or moving targets and can be used withi a few feet of the antenna to be tested.

The simulator uses a nutating probe o controllable speed and eccentricity whic moves in the focal plane of an electromagnetic lens. Plane wave returns from variety of directions and ranges are simulated when a suitable transponder, or signal generator, is connected. The anechoi chamber surrounding the probe and len absorbs unwanted internal and external interference.

**Circle Reader Service Card 117**

—*m w j*—

*(Continued on page 104)*

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Garnet
Specialists

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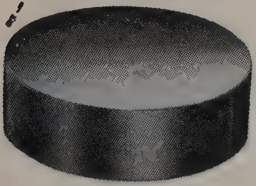
OUR NEW



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POLYCRYSTALLINE YTTRIUM ALUMINUM GARNETS

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- Loss Tangent .001
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# The Most Complete Line Of
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# OSCILLATORS

- LIGHTWEIGHT
- RUGGED
- HIGH TEMPERATURE STABILITY
- MINIMUM POWER SUPPLY REQUIREMENTS

**MODULATION CAPABILITIES AVAILABLE**

- Pulse
- Sq. Wave
- Sine Wave
- Grid Switch
- Varactor FM .2%

**MODEL 102 SERIES**

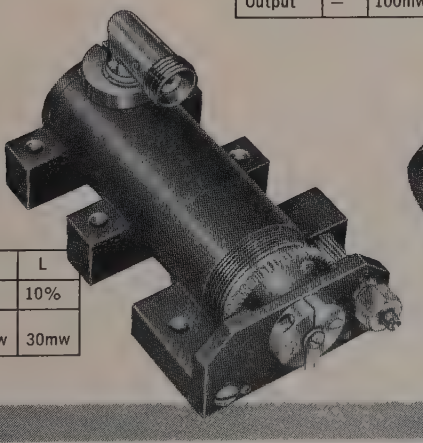
| BAND | C | S | SL | L |
|---|---|---|---|---|
| Tuning | — | 10% | 10% | 10% |
| Minimum Output | — | 30mw | 60mw | 100mw |

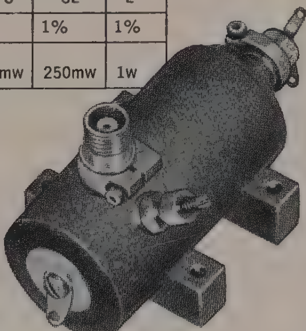
**MODEL 151 SERIES**

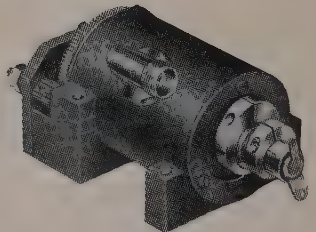
| BAND | C | S | SL | L |
|---|---|---|---|---|
| Tuning | 1% | 1% | 1% | 1% |
| Minimum Output | 20mw | 30mw | 100mw | 250mw |

**MODEL 153 SERIES**

| BAND | C | S | SL | L |
|---|---|---|---|---|
| Tuning | — | 1% | 1% | 1% |
| Minimum Output | — | 100mw | 250mw | 1w |







**MODEL 101 SERIES**

| BAND | C | S | SL | L |
|---|---|---|---|---|
| Tuning | 10% | 10% | 10% | 10% |
| Minimum Output | 10mw | 15mw | 20mw | 30mw |

**MODEL 301 SERIES**

| BAND | C | S | SL | L |
|---|---|---|---|---|
| Tuning | 10% | 10% | 10% | 10% |
| Minimum Output | 1kw | 2kw | 2½kw | 3kw |

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John Gombos Co., Inc. offers a complete service in microwave components, assemblies and sub-systems, from design through production. In addition to extensive manufacturing facilities, the company maintains complete research laboratories devoted to the development of new and more efficient microwave components. These capabilities are available to service your needs.

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EMT's new facility provides the most comprehensive line of FLEXGUIDE

E M T CORPORATION announces the election of TORE N. ANDERSON as PRESIDENT and CHAIRMAN OF THE BOARD.

E M. T. Corporation reorganized under the leadership of Tore Anderson with its Founder, John Lamb, Vice-President-Engineering, provides the most experienced design team in the Flexible Waveguide field today.

Mr. Anderson, presently Chairman of the PGMTT is a consultant to the Department of Defense and the U.S. Delegate to the International Electro-Technical Commission for Waveguide standardization.

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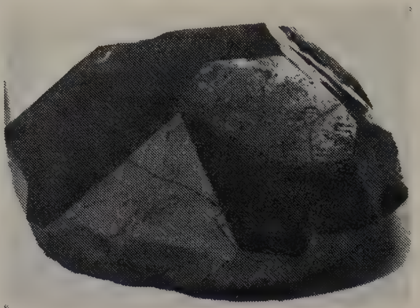
# New Products

*(Continued from page 102)*

## SINGLE-CRYSTAL MATERIALS AVAILABLE



Guaranteed-quality single-crystal materials of yttrium iron garnet and lithium ferrite are now available from stock from Airtron, a division of Litton Industries, Morris Plains, N. J.

Yttrium iron garnet (YIG), with resonance linewidth of 0.4 to 0.45 oersteds, is priced at $275 per gram, unfinished, in sizes from one to five grams. Larger sizes are available, priced on request. YIG can be furnished as polished spheres, rough-ground spheres, cubes, discs, or special shapes. Optimum operating frequency at resonance is 2 to 4 kMc.

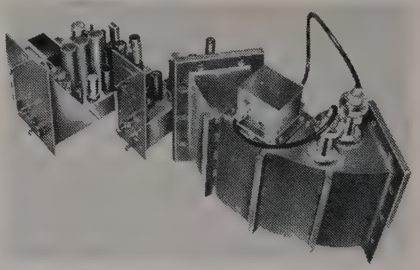
Primarily of interest to laboratories studying narrow-linewidth resonance phenomena, YIG crystals already have found their way into devices such as tunable filters and low-power RF limiters. Now, however, new application areas are opened for study, since Airtron's Solid State Materials Laboratory has demonstrated the ability to grow crystals of unprecedented size. A 95-gram crystal has been achieved.

Lithium ferrite crystals, with a linewidth of less than 10 oersteds, are priced at $250 for polished spheres from 15 to 30 mils. Frequency range of interest for this material is five to 10 kMc.

**Circle Reader Service Card 118**

*—mwj—*

## FXR OFFERS WAVEGUIDE ARC DETECTOR FOR USE IN L-BAND



A new, optically activated waveguide arc detector for use in the L-band, 1.12 - 1.7 Gc, has recently been introduced by FXR Inc., Woodside, N. Y. The addition strengthens FXR's existing line of optical waveguide arc detectors introduced last year for use in the S-band, 2.6 - 3.95 Gc, and the X-band, 8.2 - 12.4 Gc.

The waveguide arc detectors have been adapted to plumbing in the S-, X- or L-bands both in straight sections or bends.

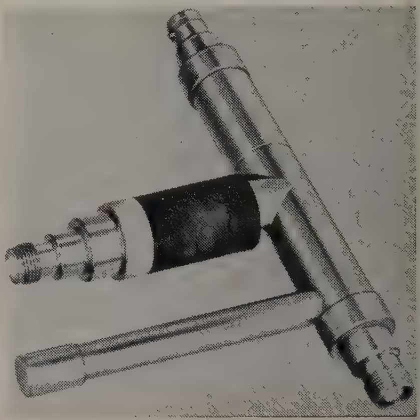
This L-band waveguide arc detector, Model S61-1, is presently in use as a final amplifier protective device on high power radar systems. Photo diodes, used as the sensing elements, are mounted external to the waveguide and are light activated through optical prisms sealed directly into the waveguide. This technique allows for high waveguide pressurization and does not materially affect the VSWR of the system.

Price of the entire S61-1 Standard System consisting of the waveguide section, arc detector assembly, arc amplifier, power supply and test light source is $1,600.00. Delivery is 60 to 120 days depending upon specifications.

**Circle Reader Service Card 119**

*—mwj—*

## COAXIAL CRYSTAL MIXERS OFFERED BY MICROLAB



A new line of crystal mixers, the XR series, has been announced by Microlab. The single-ended mixers are designed to cover the 225 - 6000 Mc region in seven overlapping frequency ranges. They are fixed tuned and require no rf adjustment over the specified frequency bands.

The XR mixers are employed as components in microwave receivers, in production testing, and as convenient laboratory instruments. They feature a low noise figure, optimum conversion loss and a compact, lightweight design suited for airborne and other military applications.

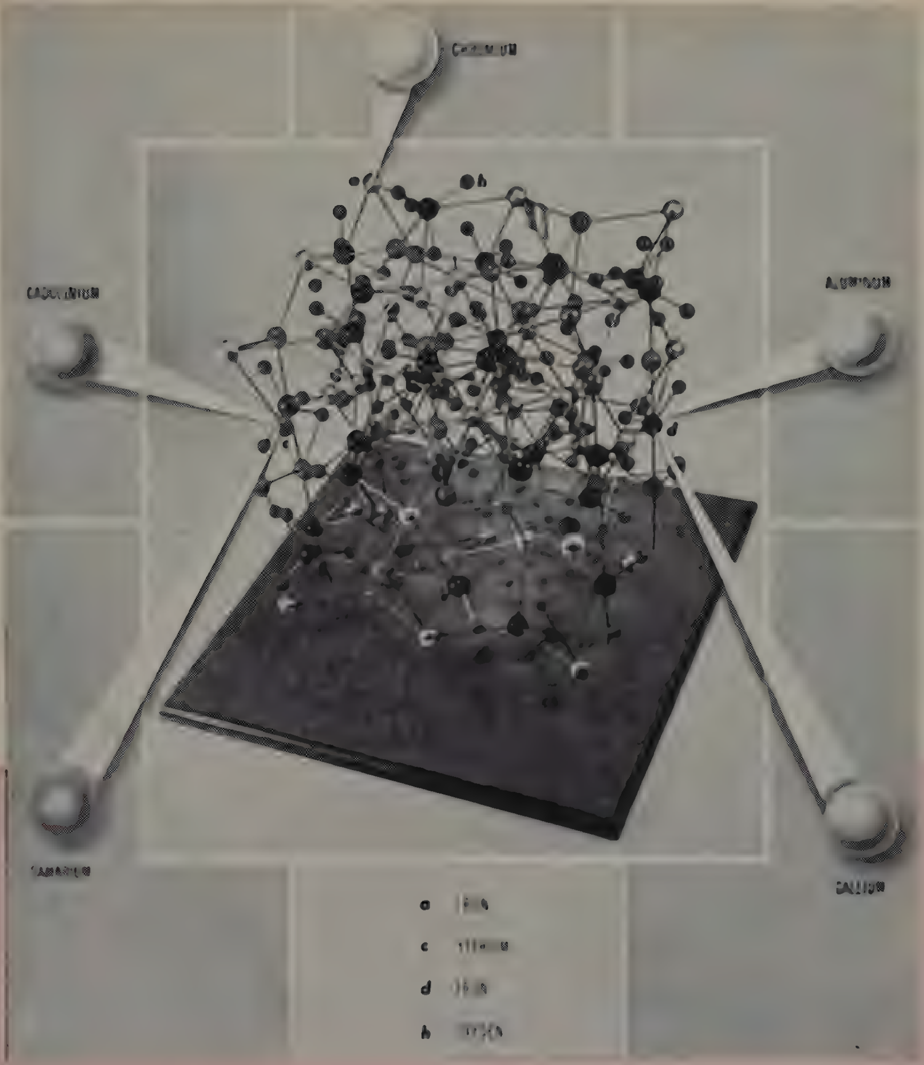
The mixers are designed to use standard ceramic cartridge type crystals and to meet military environmental specifications. There are provisions for varying the local oscillator coupling over a 13 db range. They are available with types N, C, BNC and TNC input connectors and BNC, TNC or microdot output connectors.

XR series mixers are priced at $120 and are available for immediate delivery from stock.

**Circle Reader Service Card 120**

*—mwj—*

*(Continued on page 106)*



*Model of the crystal structure of yttrium-iron garnet which is used as a basic composition into which ions of samarium, gadolinium, chromium, aluminum, or gallium, or combinations of these ions, can be substituted to produce desired microwave properties.*

# Backed by Years of Materials Research... SPERRY *Ferrimagnetic* GARNETS

● What are the microwave properties of ferrimagnetic garnet materials? That WAS the question. Years of intensive study by scientists at Sperry Microwave Electronics Company have provided the answers needed to satisfy many of your most exacting requirements. Today Sperry's ferrimagnetic garnets have no peer for microwave applications. We intend to maintain this position through a never-ending search for advanced materials, superior compositions, and new applications.

Exotic, Sperry-developed hybrid garnet compositions display many unique microwave properties. For example, some compositions possess stabilized properties as a function of temperature; others exhibit independently controlled properties; still others possess unique high power handling capabilities.

The Sperry Solid State Materials Laboratory maintains exacting formation procedures. Quality control is rigid. Laboratory equipment and manufacturing methods are unexcelled. And most important of all, technical know-how at Sperry is a proven claim.

Sperry's extensive background of materials experience is reflected in the development of many advanced solid state devices. Your inquiries for development and production of new materials and devices are invited.

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**COMMUNICATION TOWER**

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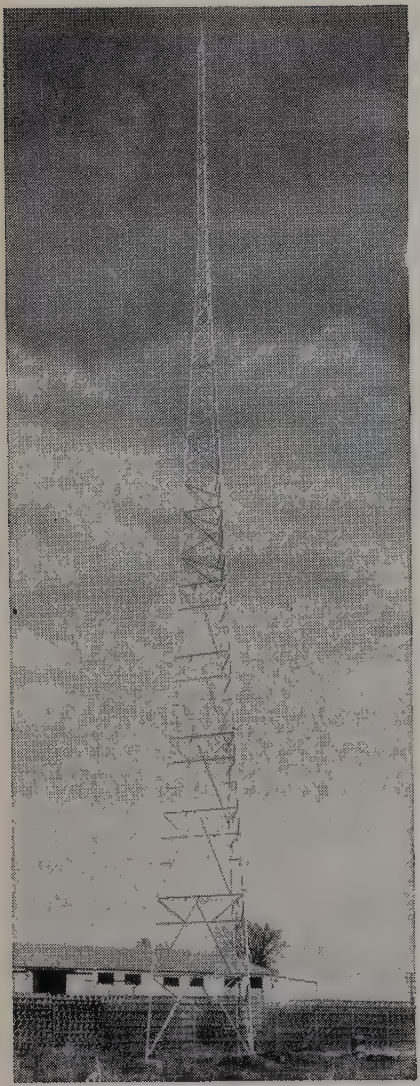

- Fully self-supporting in heights up to 170 ft.
- Rated a true HEAVY-DUTY steel tower, suitable for communication purposes, such as radio, telephone, broadcasting, etc.
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- Low in cost—does your job with BIG savings—yet has excellent construction and unexcelled design! Easily shipped and quickly installed.

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"Pioneer Manufacturers of Towers of All Kinds"

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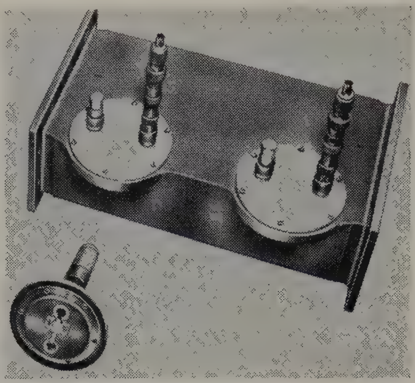
## New Products

*(Continued from page 104)*

### RESISTIVE LOOP BI-DIRECTIONAL COUPLER PRODUCED BY FXR



A new family of bi-directional resistive loop couplers is now being marketed by FXR, a division of Amphenol-Borg Electronics Corp., Woodside, N. Y. The model No. S61-2 coupler was developed for use with WR-650 waveguide in the L band. Other units are available for use in rectangular waveguide sizes from WR-2100 to WR-137.

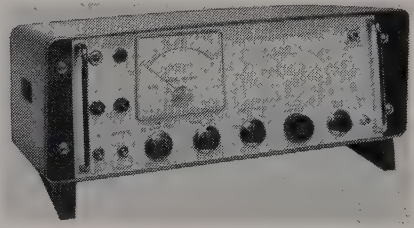
The new couplers feature high directivity and coupling attenuation in minimum space. The total length of the L band model, including the necessary WR-650 waveguide mounting section, is only 15 inches. Intended primarily for power and VSWR monitoring, the S61-2 has been used in waveguides pressurized to 30 lbs., carrying 15 Kw average and 10 Megawatts peak power.

Its coupling value is 45 db ±0.5 db including frequency sensitivity over a 10 per cent band. Directivity is 30 db minimum over the designated band from 1.27 to 1.40 Gc. Main line VSWR is less than 1.05 while the VSWR of the secondary is held to less than 1.30 maximum.

**Circle Reader Service Card 121**

—*mwj*—

### MICROWAVE SWEPT SIGNAL SOURCES MARKETED



A new line of 17 swept microwave signal sources, extending frequency ranges from a low of 0.4 - 1.2 Gc to a high of 63.0 - 75.0 Gc, has been announced by Wave Particle, Richmond, Cal., manufacturers of microwave instrumentation. This line provides swept microwave signals making possible rapid narrow and broad band analysis of reflection coefficients, attenuation, gain, pass-band, and other transfer functions.

The new line is compact and light-weight. Models measure 19 inches (standard relay rack length) x 13 inches deep x 7 inches high; weight, about 40 lbs. Price is from $2750.00 to $9000.00.

All models are available with or without auxiliary microwave levelers which can maintain power output at a constant level. Wave tubes are permanent magnet focused backward wave oscillators, or voltage tunable magnetrons. Because there are no solenoids, input power is only 135 watts and heat is minimized.

Single control adjusts sweep width; sweep rate (CW or 0.1 - 100 cps) permits either flicker-free scope presentation or graphic recording.

**Circle Reader Service Card 122**

—*mwj*—

### COAXIAL BOLOMETERS FOR MICROWAVES CONSTRUCTED

A complete series of coaxial bolometers of the 1N26 type case is now available from Microwave Semiconductor & Instruments, Inc., Richmond Hill, N. Y. The new 102 series is completely interchangeable with, and fits all, crystal detector and bolometer mounts and holders designed for the 1N26 case.

In the 102 series, the Wollaston wire element is mounted between gold plated contacts with no lossy support structure to impair the high efficiency of the bolometer.

Bias resistance values available are 200 and 100 ohms at either 8.75 or 4.5 mA. The bolometers give a true square law response curve of less than one per cent up to 0.2 mW. The 102 series is hermetically sealed and features gold plated contact surfaces which are tarnish free and corrosion resistant.

**Circle Reader Service Card 123**

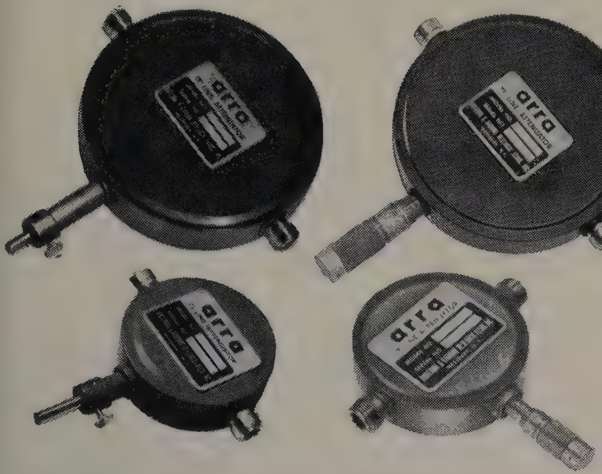
—*mwj*—

*(Continued on page 108)*

SEE COMPLETE ARRA LINE AT
**WESCON SHOW**
**BOOTH 4221**

# MICROWAVE COMPONENTS

## CONTINUOUSLY VARIABLE π LINE ATTENUATOR



### ELECTRICAL CHARACTERISTICS

- Insertion loss less than 0.2 db.
- Continuously variable for all values of attenuation.
- Max. VSWR for all values of attenuation over each band is indicated on table below.
- Meets all applicable MIL specs.
- Frequency bands from 250 MC to 11 KMC.
- Power Capacity: 10 watts average; up to 5 KW peak: special units up to 100 watts.
- Attenuation Range: Available to 60 db in most bands.
- Resettable to ±0.1 db.
- Calibration Accuracy: 0.2 db or 1%, whichever is greater.

### OCTAVE BANDWIDTH (5" DIAMETER)

| Micrometer Model No. | "S" Type Model No. | Freq. KMC | Min. Atten. Range DB. | Max. VSWR | Unit Price** |
|---|---|---|---|---|---|
| 1414-10 | 1416-10 | .25- .50 | 10 | 1.5 | $270. |
| 2414-20 | 2416-20 | .50- 1.0 | 20 | 1.5 | 260. |
| 3414-30 | 3416-30 | 1.0 - 2.0 | 30 | 1.4 | 240. |
| 4414-40 | 4416-40 | 2.0 - 4.0 | 40 | 1.3 | 240. |
| 5414-40 | 5416-40 | 4.0 - 7.0 | 40 | 1.3 | 240. |
| 6414-40 | 6416-40 | 7.0 -11.0 | 40 | 1.3 | 240. |

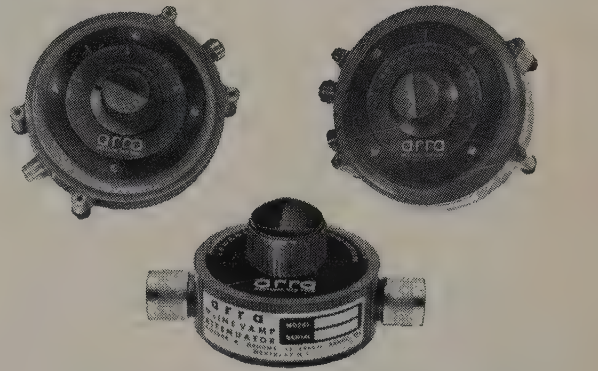
### MULTI-OCTAVE BANDWIDTH (5" DIAMETER)

| | | | | | |
|---|---|---|---|---|---|
| 2-3414-30 | 2-3416-30 | .8 - 2.5 | 30 | 1.5 | $260. |
| *3-6414-10 | 3-6416-10 | 1.0 - 9.0 | 10 | 1.5 | 150. |
| 4-5414-30 | 4-5416-30 | 2.0 - 6.0 | 30 | 1.3 | 230. |

### 3" DIAMETER SERIES (OCTAVE BANDWIDTH)

| | | | | | |
|---|---|---|---|---|---|
| 4424-20 | 4426-20 | 2.0 - 4.0 | 20 | 1.3 | $240. |
| 5424-20 | 5426-20 | 4.0 - 7.0 | 20 | 1.3 | 240. |
| 6424-20 | 6426-20 | 7.0 -11.0 | 20 | 1.3 | 240. |

## CONTINUOUSLY VARIABLE π LINE VAMP ATTENUATOR



### ELECTRICAL CHARACTERISTICS

- Insertion loss less than 0.5 db.
- Continuously variable for all values of attenuation.
- VSWR: 1.5 Maximum for all values of attenuation.
- Frequency Bands: From 500 MC to 11 KMC.
- Power Capacity: 10 watts average; up to 5 KW peak: special units up to 100 watts.
- Attenuation Range: Available to 60 db in most bands.
- Attenuation essentially linear with drive.

### MECHANICAL CHARACTERISTICS

- Meets all applicable MIL specs, such as
  1. MIL E 4970—shock, vibration, exposure.
  2. MIL I 006181C—radio interference
  3. MIL QQ-M-151A — salt spray
- Full range of attenuation in less than 165 degrees rotation.
- Calibration dial in 1 degree increments or directly calibrated.
- Accurate Resettability to 1.0°, with vernier to 0.1°.
- Attenuation increases with counter clockwise rotation.
- Zero Backlash.
- Type N Female connectors.
- Adaptable for manual, servo, or remote control.
- 0.1 degree vernier on 5" models not directly calibrated.
- 3" calibration dial for 5" models.
- $2\frac{9}{16}$" calibration dial for 3" models.
- Both may be removed for remote operation.
- Mounting information on request.

### OCTAVE BANDWIDTH
(OTHER MODELS HAVE FLAT ATTENUATION CHARACTERISTICS)

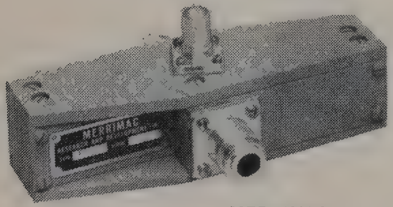
| Model No. | Diameter | Freq. KMC | Min. Atten. Range DB. | Max. VSWR | Unit Price |
|---|---|---|---|---|---|
| 2614-15 | 5" | .5-1.0 | 15 | 1.50 | $350. |
| 3614-30 | 5" | 1.0-2.0 | 30 | 1.50 | 350. |
| 4614-30 | 5" | 2.0-4.0 | 30 | 1.50 | 350. |
| 5624-30 | 3" | 4.0-7.0 | 30 | 1.50 | 350. |
| 6624-30 | 3" | 7.0-11.0 | 30 | 1.50 | 300. |

**arra**

**ANTENNA AND RADOME RESEARCH ASSOCIATES**
27 BOND STREET · WESTBURY, NEW YORK

NEW
FROM
Merrimac

ELECTRONICALLY CONTROLLED COAXIAL ATTENUATOR



MERRIMAC AAE-1

**Flat — Wide band — Sweepable through full attenuation range of 15 db**

One unit to cover 200 to 600 mc
Low VSWR—less than 1.3 from 300 to 500 mc, under 1.6 overall
Attenuation vs. Frequency—flat to 15 db
Insertion Loss—less than 1 db from 300 to 500 mc, under 1.6 overall
Low bias power—only a few mw required
Space saving—3¼" from input to output

The characteristics of the attenuator are insensitive to RF power below 15 mw average and operation at power levels in excess of 250 mw is possible.
A notable feature—when RF power exceeds 150 mw average, a special triggering circuit can be provided making the attenuator self-biasing.
Available also as a broad band modulator, model MAE-1, with 15 db of dynamic range.

TYPICAL APPLICATIONS

- Sweepable Attenuator
- Modulator
- Sensitivity Time Control for Radar Systems

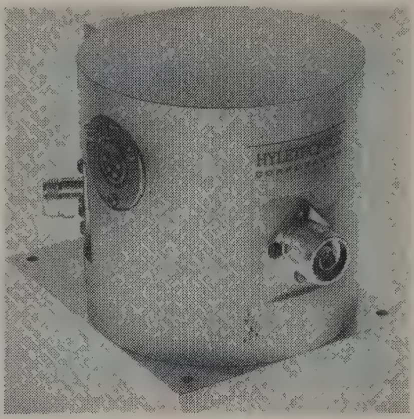
*For detailed information, write or call:*

Merrimac
Research and Development, Inc.
517 Lyons Avenue • Irvington, New Jersey
ESsex 1-1616

## New Products

*(Continued from page 106)*

### HYLETRONICS PRODUCES CIRCULATOR SWITCHES AT L-BAND



Hyletronics Corp., Burlington, Mass., announces new L-band ferrite circulator switches. Used as non-reciprocal SPDT switches, they have applications in receiver protection, antenna switching, and radiometry.

Designed to operate below ferromagnetic resonance to reduce drive requirements, they can be switched in times down to 30 $\mu$sec. High speed switching is accomplished through the use of thin-walled ground planes in the strip-transmission line to eliminate the shorted turn effect and eddy current losses. Model SL1 exhibits over 20 db of isolation and less than 0.5 db insertion loss over the band 1250-1350 Mc.

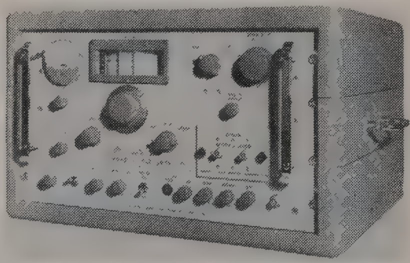
Model SL2 is also available at 1420 Mc and provides greater than 30 db of isolation and less than 0.2 db insertion loss.

Delivery is from four to six weeks.

**Circle Reader Service Card 124**

—*mwj*—

### JERROLD INTRODUCES 900B SWEEP SIGNAL GENERATOR



A new Sweep Signal Generator (900B) which features a high degree of stability for sweep widths as narrow as 10 kc, as well as wide sweep width capabilities as broad as 400 Mc, has been introduced by the Jerrold Electronics Corp., Philadelphia, Pa.

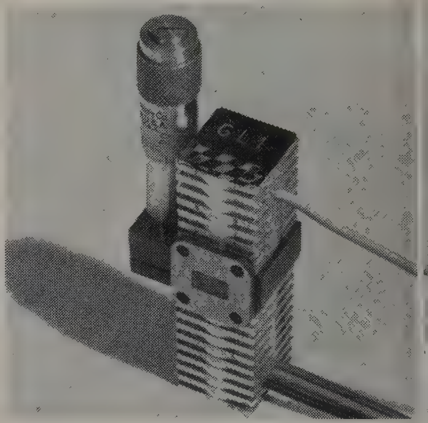
Many features found only in signal generators have been included in the 900B, which can handle most sweep signal requirements from 500 kc to 1200 Mc. The generator features an accurately calibrated frequency dial; built-in crystal controlled harmonic markers, at one, 10, and 100 Mc intervals, with front panel controls. It includes a built-in precision attenuator, zero — 50 db, in 10 db steps, as well as a built-in dc coupled oscilloscope preamplifier.

The 900B, combines the functions of much of the test equipment now required for RF sweep frequency measurements between 500 kc and 1200 Mc, and can be applied to Video, IF, VHF, and UHF communication requirements.

**Circle Reader Service Card 125**

—*mwj*—

### GEISLER INTRODUCES COMPLETE LINE OF MILLIMETER KLYSTRONS



Geisler Laboratories, Woodland Hills, Cal., announces the introduction of a complete line of millimeter klystrons. The first units in the series will cover the 26.5 - 40 kMc frequency range.

The klystrons feature extreme ruggedness, long life, and high reliability. Advanced design concepts assure high power output, wide frequency coverage, and excellent versatility. Model GK-70, operates in the frequency range of 26.5 — 31.5 kMc.

**Circle Reader Service Card 126**

—*mwj*—

### B.F. GOODRICH DEVELOPS HIGH PERFORMANCE MICROWAVE ABSORBERS

B.F. Goodrich Sponge Products, Shelton, Conn., has announced a new line of VHP (very high performance) microwave absorbers to improve the performance of anechoic chambers.

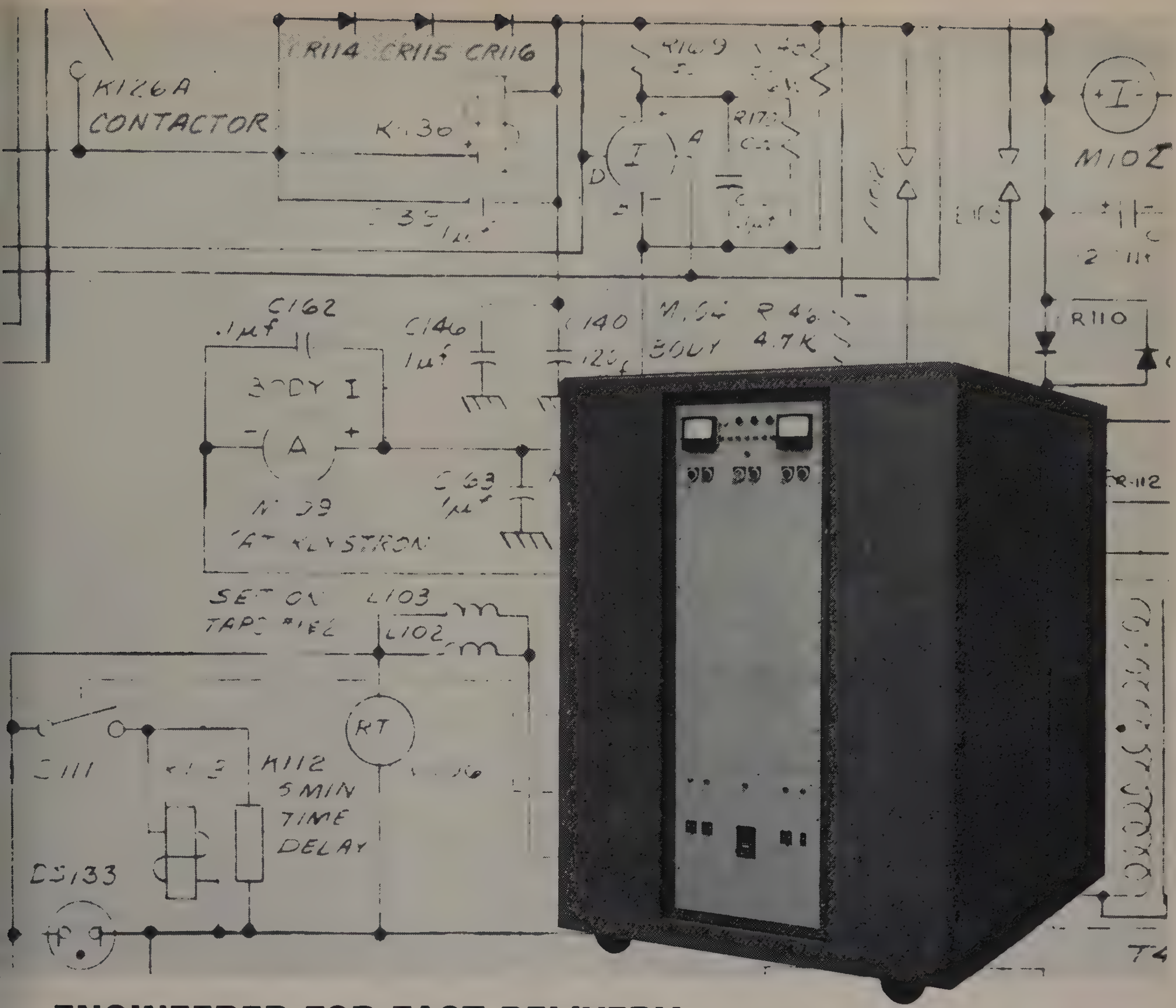
The new absorbers eliminate baffles with lower reflection levels than previously existed by application to rear wall and/or center region; and yield chambers with reduced cross-section by the material's claimed excellent wide-angle absorption.

Type VHP-18 material at X band has the following features: reflection down by approximately 60 db for angles near normal incidence; reflection down 40 - 50 db for both polarizations at angles of 60° - 65° from normal incidence (angles most often encountered in anechoic chamber sidewalls), and attenuation through the material in excess of 50 db.

**Circle Reader Service Card 127**

—*mwj*—

*(Continued on page 112)*



# ENGINEERED FOR FAST DELIVERY ...STANDARD POWER SUPPLIES FROM 10 TO 600 KVA

Functional design is an important advantage of power supplies offered by Radiation at Stanford (formerly Levinhal). They are carefully engineered to permit rapid production and prompt delivery of units with the exact characteristics you require.

Radiation at Stanford power supplies offer maximum flexibility—whatever your application—and are distinguished by these standard features:

- Choice of output—10 to 600 kva; 10 to 55 kv
- Output continuously variable from 0 to full voltage
- Reversible output polarity
- Low ripple—down to 0.05%
- Protection against equipment damage and personnel hazard by complete set of interlocks with fail-safe indicators
- Protective circuitry for all meters against load short-circuit damage
- Circuit breakers throughout
- Magnetic component protection against over-voltage by spark gaps and auto-valves
- Simplified control—through use of "System ON-OFF," "High Voltage ON-OFF," and "High Voltage RAISE-LOWER" controls

*Special brochure* contains complete technical information on our standard line of "custom" supplies. For your copy, write or call Radiation at Stanford, 3180 Hanover Street, Palo Alto, California.

Make a note to visit
Radiation's displays at WESCON.

RADIATION
at Stanford

All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

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# PROGRAM EXCERPTS

## *Of Interest to Microwave Engineers*

The Western Electronic Show and Convention (WESCON) will be held in San Francisco from August 22-25. The entire program will take place in the famed Cow Palace. Nearly 1200 booths will carry displays and 40 full technical sessions are scheduled.

The technical program will feature about 120 authors and nearly as many critique panel members, who will cover the range of major engineering disciplines. Special emphasis will be placed on such "breakthrough" subjects as coherent light generators and quantum electronics. There will be special exhibit areas for distributor-marketed products, production and materials, and publishers.

Portions of the WESCON program of special interest to microwave engineers are reprinted as follows:

## TUESDAY, AUGUST 22, 1961

### Session 1: BROADBAND ANTENNAS

*Room A/10:00 a.m. - 12:30 p.m.*

1/1 "Log-Periodic Resonant-V Arrays," by P. E. Mayes and R. L. Carrel, University of Illinois, Urbana, Illinois.

1/2 "Design Criteria For Log Periodic Antennas," by Claes T. Elfving, Sylvania Electric Products Inc., EDL, Mountain View, California.

1/3 "Properties Of A Pair Of Wire Grids For Use In Lens-Type HF Antennas," by M. Andreasen and R. L. Tanner, Stanford Research Institute, Menlo Park, California.

### Session 2: NEW MICROWAVE ELECTRON DEVICES

*Room B/10:00 a.m. - 12:30 p.m.*

2/1 "The Coaxial Magnetron, A Superior Microwave Power Source," by H. M. Olson and L. H. Von Ohlsen, Bell Telephone Laboratories, Laureldale, Pa.

2/2 "Analysis Of A Crossed-Field Waveguide Amplifier," by W. C. Brown and G. E. Dombrowski, Spencer Laboratory, Raytheon Co., Burlington, Mass.

2/3 "Beam-Plasma Amplifiers," by M. A. Allen and G. S. Kino, Stanford University, Stanford, Cal.

### Session 6: CURRENT AND FUTURE RADIO ASTRONOMY AND TECHNIQUES

*Room A/2:00 p.m. - 4:30 p.m.*

6/1 "Low Noise Receivers," by P. D. Strum, Applied Technology, Inc., Palo Alto, Cal.

6/2 "Developments In Antenna Techniques For Radio Astronomy," by Emile-Jacques Blum, Observatory of Paris, Meudon, France.

6/3 "Radio Astronomy In The Solar System," by E. A. Lilley, Harvard University, Cambridge, Mass.

6/4 "Radio Astronomy Beyond The Planetary System," by Gart Westerhout, Leiden, Netherlands.

## WEDNESDAY, AUGUST 23, 1961

### Session 11: RADIO ASTRONOMY ANTENNAS

*Room A/10:00 a.m. - 12:30 p.m.*

11/1 "The Diffraction Theory of Large Aperture Spherical Reflector Antennas by A. C. Schell, Air Force Cambridge Research Laboratories, Bedford, Mass.

11/2 "Correlation Antennas With Non-Uniformly Spaced Elements For Incoherent Sources," by L. C. Davenport and C. J. Drane, Air Force Cambridge Research Laboratories, Bedford, Mass.

11/3 "A High Resolution Radio Telescope by J. L. Yen and D. A. MacRae, University of Toronto, Toronto, Canada.

### Session 14: DETECTION AND SIGNAL PROCESSING

*Room D/10:00 a.m. - 12:30 p.m.*

14/1 "Crosscorrelation With Binary Signals," by G. R. Cooper, Purdue University, Lafayette, Ind.

14/2 "Threshold Comparison of Phase-Lock, Frequency-Lock and Maximum Likelihood Types Of FM Discriminators," by J. J. Spilker, Jr., Lockheed Missiles and Space Division, Palo Alto, Cal.

14/3 "Classification And Evaluation Of Coherent Synchronous Sampled Data Telemetry Systems," by A. J. Viterbi, JPL, California Institute of Technology, Pasadena, Cal.

### Session 15: MICROWAVE COMPONENTS AND TECHNIQUES

*Room E /10:00 a.m. - 12:30 p.m.*

15/1 "Microwave Variable Attenuator And Modulators Using PIN Diodes," b J. K. Hunton and A. G. Ryals, Hewlett Packard Company, Palo Alto, Cal.

15/2 "The Isomodulator," by Howar Scharfman, Raytheon Company, Waltham Mass.

15/3 "A Practical Approach To The Design Of Parametric Frequency Multipliers," by G. Luettgenau, J. Williams an H. Miyahira, Pacific Semiconductors, Inc Lawndale, Cal.

## THURSDAY, AUGUST 24, 1961

### Session 21: POINT-TO-POINT COMMUNICATIONS VIA SATELLITE RELAYS

*Room A/10:00 a.m. - 12:30 p.m.*

21/1 "Twelve Advantages Of Stationar Satellite Systems For Point-To-Point Communication," by S. G. Lutz, Hughes Research Laboratories, Malibu, Cal.

21/2 "Techniques For Incoherent Scatte Communication," by D. P. Harris, Lockheed Missiles and Space Division, Pal Alto, Cal.

21/3 "The Operational Analysis Of New York-London Communication Satellite Link by Machine Calculation," b W. Williams, Jr., and L. K. Arquette Bendix Systems Division, Ann Arbor Mich.

### Session 23: NANOSECOND TECHNIQUES

*Room C/10:00 a.m. - 12:30 p.m.*

23/1 "Nanosecond Pulse Measurements, by C. N. Winningstad, Tektronix Co Beaverton, Ore.

23/2 "A Triggered Nanosecond Pulse Light Source," by T. G. Innes and Q. A Kerns, University of California Radiatio Laboratory, Berkeley, Cal.

23/3 "Analysis And Measurement o Phase Characteristics In Microwave Systems," by P. Lacy, Wiltron Co., Palo Alt Cal.

*(Continued on page 112)*

# MIL/SPEC

# GM-07-59-2617A

## ...Implemented by Capehart's INTERDICT GROUP

A veritable thicket of specifications has grown up around radio frequency interference measurements. Specification GM-07-59-2617A appears to be one of the thorniest. If you are having problems implementing this, or are experiencing any other difficulty connected with RFI, contact the INTERDICT Group from Capehart.

INTERDICT (for Interference Detection and Interdiction by Countermeasures Team) is a unique service. It began with the numerous field studies our engineers were carrying out. It grew into a series of mobile RFI measurement vans, an expanded force of engineers, a manual on RFI prediction by mathematical procedures, cognizance of all current military and industrial communications/electronic equipment, and formal organization into a team led by Dr. Joseph Vogelman, widely-known authority on RFI detection and elimination.

The engineers from INTERDICT are completely competent to aid in establishing: systems analysis, design limitations, criteria and test procedures. Follow through by INTERDICT engineers in the actual performance of these tests assures complete implementation of GM-07-59-2617A or any other relevant MIL Spec*. They have performed numerous systems and site analyses resulting in the prediction, detection and elimination of interference at such complex sites as Cape Canaveral and Vandenberg AFB, frequently before r-f interference occurred. They can offer you studies of this magnitude, or of very limited application, depending on your needs. INTERDICT possesses the men, the vans, the materiel, and the experience to analyze a complete proposed missile system, an individual site, or a single piece of installed equipment. The "package" can be tailored to the requirement.

The INTERDICT Group analyzes a proposed system for all r-f radiation sources, makes the necessary field measurements, predicts and determines the causes of interference, and recommends the proper remedial action. Should this latter require any equipment not commercially available, Capehart's quick-reaction engineering and model shop can provide what is needed very rapidly.

Capehart's INTERDICT offers the first world-wide packaged service to analyze and counteract radio frequency interference. It also provides for elimination of electromagnetic radiation hazards to personnel and materials such as squibs, ammo, fuel. All service is performed in compliance with applicable MIL Specifications such as that noted. To avail yourself of these unusual services, contact:

*Such as MIL-I-26600, I-6051, T-9107, S-10379, etc.

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INTERDICT GROUP, Dept. D-1, CAPEHART CORPORATION
87-46 123rd Street, Richmond Hill 18, New York • HIckory 1-4400

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## Wescon Schedule

*(Continued from page 110)*

### Session 25: COHERENT OPTICAL EMISSION

*Room E/10:00 a.m. - 12:30 p.m.*

25/1 "Fundamental Aspects Of Optical Masers," by J. R. Singer, University of California, Berkeley, Cal.

25/2 "Some Potentialities of Optical Masers," by B. M. Oliver, Hewlett-Packard Co., Palo Alto, Cal.

25/3 "The Ruby Maser As A Light Amplifier," by P. P. Kisliuk and W. S. Boyle, Bell Telephone Laboratories, Murray Hill, N. J.

25/4 "Alkali Vapor Optical Masers," by H. Cummins, Columbia University, New York, N. Y.

25/5 "Optical Maser Studies At Lincoln Laboratory," by H. A. Bostick, Lincoln Laboratories, Lexington, Mass.

25/6 "Repetitive Hair-Trigger Mode Of Optical Maser Operation," by M. L. Stitch, E. J. Woodbury, J. H. Morse, Hughes Aircraft Co., Culver City, Cal.

### Session 27: MICROWAVE TUBES AND PARAMETER MEASUREMENTS

*Room B/2:00 p.m. - 4:30 p.m.*

27/1 "A Broad-Banding Theory Of The Klystron Amplifier Output Circuit," by C. Romiguiere, Compagnie Francaise Thomson-Houston, Paris, France.

27/2 "Measurement Of Impedance Offered To The Beam By Klystron Broad-Band Output Circuit," by M. Lakits, Compagnie Francaise Thomson-Houston, Paris, France.

27/3 "The Use Of Quasi-Static Mode Approximations In The Design Of Broad-Band, Slow-Wave Structure Impedance Matches," by W. Raub, Microwave Electronics Corp., Palo Alto, Cal.

27/4 "A 50-Microwatt BWO And 0.5 Watt TWT For CW Operation At 50-60 KMC," by D. O. Melroy, Bell Telephone Laboratories, Murray Hill, N. J.

### Session 29: SPECTRUM UTILIZATION FOR SPACE COMMUNICATIONS

*Room D /2:00 p.m. - 4:30 p.m.*

29/1 "Impact Of Space Communication On The Spectrum," by J. Hacke, Jr., General Electric Co., Santa Barbara, Cal.

29/2 "Interference Considerations For Communications Satellites," by N. Berger, J. Downing, F. Fulton and D. Harris, Lockheed Missiles and Space Division, Palo Alto, Cal.

29/3 "Channel Utilization By Intermittent Transmitters," by F. Fulton, Jr., Lockheed Missiles and Space Division, Palo Alto, Cal.

### Session 30: QUANTUM DEVICES

*Room E/2:00 p.m. - 4:30 p.m.*

30/1 "Design and Operation Of An Experimental Colidar," by E. J. Woodbury, J. M. Morse, R. S. Congleton, and M. L. Stitch, Hughes Aircraft Company, Culver City, Cal.

30/2 "A Solid State Spin Echo Memory System For A Microwave Digital Computer," by L. K. Wanlass and J. R. Singer, University of California, Berkeley, Cal.

30/3 "The Ammonia Beam Maser As A Standard Of Frequency," by J. A. Barnes, D. W. Allan, and A. E. Wainwright, National Bureau of Standards, Boulder, Colo.

### FRIDAY, AUGUST 25, 1961

### Session 31: PROPAGATION STUDIES FOR NEW COMMUNICATIONS TECHNIQUES

*Room A/10:00 a.m. - 12:30 p.m.*

31/1 "Laboratory Simulation Of VLF Propagation And Underground Antenna Performance," by T. C. Larter, M. E. Louapre and A. Stogryn, Space Electronics Corp., Glendale, Cal.

31/2 "Synchronized-Oblique Ionosphere Sounding For HF OWF Determination," by R. D. Baker, R. D. Egan and L. D. Seader, Granger Associates, Palo Alto, Cal.

31/3 "Free Electron Scatter As A Communication Mode," by A. M. Peterson, Stanford University, and Stanford Research Institute, Menlo Park, Cal.

### Session 40: MICROWAVE SOLID STATE DEVICES

*Room E/2:00 p.m. - 4:30 p.m.*

40/1 "An Electronically-Tunable Band-Reject Filter," by K. L. Kotzebue, Watkins-Johnson Company, Palo Alto, Cal.

40/2 "A Non-Degenerate Traveling Wave Parametric Amplifier," by K. P. Grabowski, Hughes Aircraft Co., Fullerton, Cal.

40/3 "Magnetically-Tunable Non-Reciprocal Band Pass Filter Using Ferrimagnetic Resonators," by Cumar Patel, Stanford University, Stanford, Cal.

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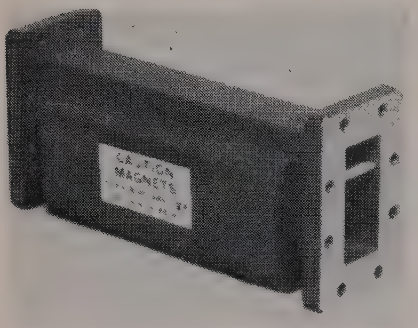
## New Products

*(Continued from page 108)*

### KEARFOTT OFFERS WAVEGUIDE C-BAND ISOLATOR



A new high-performance waveguide C-Band isolator is now being marketed by Kearfott Microwave Division, General Precision, Inc., Van Nuys, Cal., manufacturers of precision microwave components and test equipment.

The new high-performance waveguide C-Band isolator will fit many requirements where extremely high isolation and low insertion loss is required. Units are available with rectangular (EIA #CMR-137) or circular flanges (UG344/U).

Outstanding features of the new high-performance C-Band isolator are: frequency ranges: 5.4 - 5.9 kMc, 5.9 - 6.425, 6.575 - 6.875, 6.875 - 7.125, 7.125 - 7.655, 7.650 - 8.400 kMc; isolation: greater than 60 db; insertion loss: 1.0 db max.; VSWR: 1.2 max.; temperature range: —40°C to +70°C; typical data: isolation, 70 db; insertion loss, 0.6 db; VSWR, 1.08; power handling capability, 10 watts average. length: 4.75 or 5.00 inches.

**Circle Reader Service Card 128**

— *mwj* —

### HIGH-SPEED COAXIAL SWITCHES INTRODUCED FOR MICROWAVE APPLICATIONS

Thirteen high-speed, all-solid-state coaxial switches for use in medium power microwave switching applications have been introduced by Microwave Associates Inc., Burlington, Mass.

The MA-3464 series of switches are available in single-pole single-throw and multiple pole, multiple-throw configurations and operate at frequencies ranging from 150 Mc - 4700 Mc (UHF to C-band).

The switches are designed for all applications in which ultra-fast switching speeds, combined with small size, light weight, rugged construction, and all-solid-state reliability are desired. A major advantage of the MA-3464 switches is the low driving power required. It ranges from 10 - 100 milliwatts. Insertion loss is as low as 1.0 db (maximum) in the "closed" position and isolation up to 35 db (minimum) is provided in the "open" condition.

Eleven of the thirteen switches in this new series handle 150 watts peak power (with 0.001 duty cycle) and two switches for operation at 1100 Mc handle up to 10 kilowatts of peak power (0.001 duty cycle).

**Circle Reader Service Card 129**

— *mwj* —

*(Continued on page 119)*

# A VARACTOR FOR EVERY PURPOSE

# 3 WATTS at 1120 Mc from 7 WATTS at 140 Mc

220 new epitaxial silicon high power varactors in four package styles — subminiature glass case • double-ended cartridge • "pill" case • new "coaxial pill" case — all hermetically sealed, make *this* kind of harmonic generation possible now.

A WIDE VARIETY of PIV ratings and capacitance values allows selection of the optimum diode in each case style for your circuit application.

The data reported below was obtained by the Waveguide Systems Division of Microwave Associates* in a tandem chain of three doubler stages, each using a selected single Microwave Associates' epitaxial silicon high power varactor.

This high power output and remarkable harmonic efficiency was achieved without boosters, without power supply, in passive circuits.

Since the initial introduction of varactors on a commercial basis by Microwave Associates, we have continued to lead the way in varactor technology.

Microwave Associates' unsurpassed varactor circuit capabilities are your assurance of varactors tested to meet specific harmonic generation requirements.

The Waveguide Systems Division of Microwave Associates offers capabilities for the design and delivery of complete harmonic generator circuits.

Write for a copy of "SELECTION OF VARACTORS FOR POWER HARMONIC GENERATION" and for the 1961 Semiconductor Division Short Form Catalog.

* Support received by (USAF) ETL Aeronautical Systems Division Contract #AF33 (616) — 7232.

## with MICROWAVE ASSOCIATES EPITAXIAL SILICON HIGH-POWERED VARACTORS

**MICROWAVE ASSOCIATES, INC.**
SEMICONDUCTOR DIVISION

Burlington, Massachusetts • Browning 2-3000
Western Union Fax • TWX: Burlington, Mass. 942

Export Sales: MICROWAVE INTERNATIONAL CORP., 36 W. 44th Street, N.Y.C., N.Y., U.S.A. Cable MICROKEN

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WESCON BOOTH 123

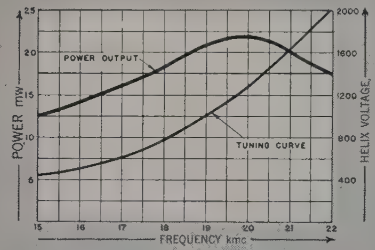
immediate
BWO
delivery

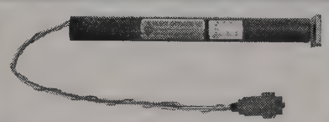
Why is it, we've been asked, are there more people making BWO promises than there are people making BWOs?

We can only speak for ourselves. We have many types of BWOs on the shelf, from 1 to 22 kmc, because if we didn't have them we wouldn't be in business. BWOs are our business, not a sideline.

But delivering a BWO when you need it isn't our only concern; we want you to be able to depend on it after it gets there. You can. Stewart BWOs are **guaranteed** for a minimum of 500 hours of operation, and normally outlive their guarantees many times over.

Our newest BWO is the Type OD-15-22, which gives you 10 to 20 mw output from 15 to 22 kmc. Here's how its performance looks on a chart:





Have you seen our newest BWO catalog? Or do you have an interest in special tubes, such as permanent-magnet-focused BWOs or traveling wave amplifiers? Drop us a note.

**STEWART ENGINEERING COMPANY**
**Santa Cruz 2, Calif.**

# LETTERS TO THE EDITOR

Mr. Marshall C. Pease
Associate Editor, *the microwave journal*
Brookline 46, Mass.

Dear Mr. Pease:

I read with a great deal of interest your paper "The Role of Matrix Algebra" in the May 1961 issue of *the microwave journal.* I became aware of the importance of matrix algebra to the microwave theoretician only a short time ago by way of another branch of mathematics and as I read your paper, I anticipated some mention of it.

This other discipline has been "a very powerful tool for the quantum physicist;" it is quite closely connected with matrices and possibly "appears even more esoteric." The mathematics of this technique have been applied to problems of waveguide junctions by a very limited number of people, and it is rather surprising to me that more attention has not been forthcoming. Perhaps it was significant that the microwave hierarchy recognized the important contribution of one author who has written on this subject by awarding him the 1959 Microwave Prize. However, the ensuing years have not produced, to my knowledge, any further papers using these methods. I would venture to say that the electron device analyst would do himself a favor to learn the fundamentals of this discipline, and the applications would become apparent as he pursues his problems.

If you have not already guessed the area of mathematics to which I am referring, it is the theory of groups or group algebra. I had the opportunity to attend a seminar this year on physical applications of group theory. Although most of the time was devoted to understanding the fundamentals of the mathematics, the emphasis was on those particulars that are of greatest use to the physicist. Of course, the applications are chiefly in the fields of quantum mechanics and solid state physics. However, the application to symmetric waveguide junctions was discussed briefly in this course and provided a starting point for reading further into literature.

As I mentioned before, I was surprised to find so little interest shown in the subject by people in the microwave field. Perhaps it is only a matter of informing them of the usefulness of this technique. Perhaps a review of what has been accomplished thus far would stimulate more interest. Whatever is necessary, I am sure that when more widespread mastery of the fundamentals has been achieved, the applications to electromagnetic problems will unfold rapidly.

I would be interested very much in hearing the opinions of both you and your colleagues on this matter.

Yours truly,
R. A. Sparks
The Johns Hopkins University
Silver Springs, Maryland

—*mwj*—

Mr. R. A. Sparks

Dear Mr. Sparks:

I have received your letter on m editorial, "The Role of Matrix Algebra with considerable interest.

You raise the question of why did not refer to the paper by B. A. Au on "The Synthesis of Symmetrical Wav guide Circulators," (MTT-7,238 - 24 April 1959). This paper did, indeed, u some elegant and powerful methods analysis, and is a good example of th use of such methods on engineering problems of practical importance.

You have yourself indicated on reason why I did not refer to it when, i your second paragraph, you refer to "th theory of groups or group algebra." Aul does use matrix algebra, but I tak it you would agree that the emphasi in his paper is more on the group theoretical methods than on the matrix algebra. Since my editorial was specificall concerned with matrix theory, this emphasis on group theory made Auld's paper elegant as it is, somewhat marginal to m purpose.

A more important reason is tha I had no intent to give a complete review of all applications of matrix algebra in electronics. Nor was I attempting to predict all future uses. I was concerned simply with the question of whether ther is a valid present need. I showed, I believe, that there was such a need in th general field of coupled mode theory. I there are additional needs in other area of microwave electronics, then so muc the better. But there is at least one.

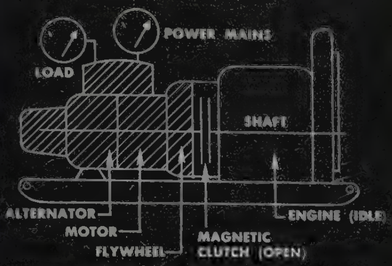
This problem has had pertinence to my own work. I have published severa papers, recently, on various aspects o coupled mode theory using reasonably abstract matrix techniques. The same results though perhaps not easily with the same generality, could have been obtained by a formalism and with methods that are more familiar to electronic scientists and engineers. I, therefore, had a responsibility to decide whether there were real advantages to the abstract matrix formulation that would outweigh the disadvantage of its unfamiliarity (cf. my recent editorial on "The Problem of Elegance"). The decision required an objective (so far as possible) study of the future needs of this field. I at least satisfied myself that the need for such methods existed, and that the problem was becoming more critical, rather than less. This editorial was, in part, a result of that appraisal.

You also raise the question of whether or not group theoretic techniques may not be applicable and valuable in areas to which it has not so far been applied. While, for the reasons outlined

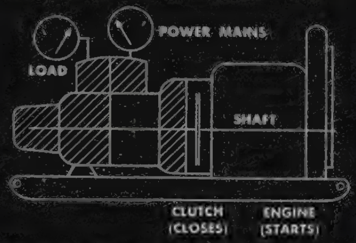
*(Continued on page 116)*

# MICRO POWER . . .

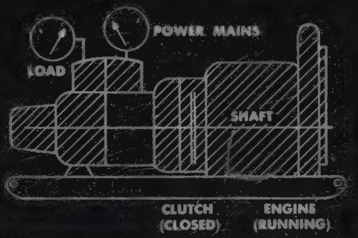
## HOW IT WORKS



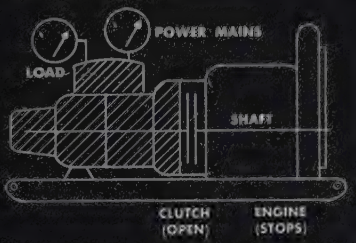
COMMERCIAL POWER MAINS NORMAL. LOAD SUPPLIED BY MOTOR AND ALTERNATOR.



COMMERCIAL POWER MAINS FAIL. LOAD SUPPLIED TEMPORARILY BY FLYWHEEL. STANDBY ENGINE STARTS, MOTOR DISCONNECTED FROM MAINS.



STANDBY ENGINE AND ALTERNATOR SUPPLY POWER TO LOAD. SWITCHOVER ACCOMPLISHED WITHOUT LOSS OF USABLE VOLTAGE.



COMMERCIAL POWER RESTORED. LOAD SUPPLIED ONCE MORE FROM MOTOR AND ALTERNATOR.

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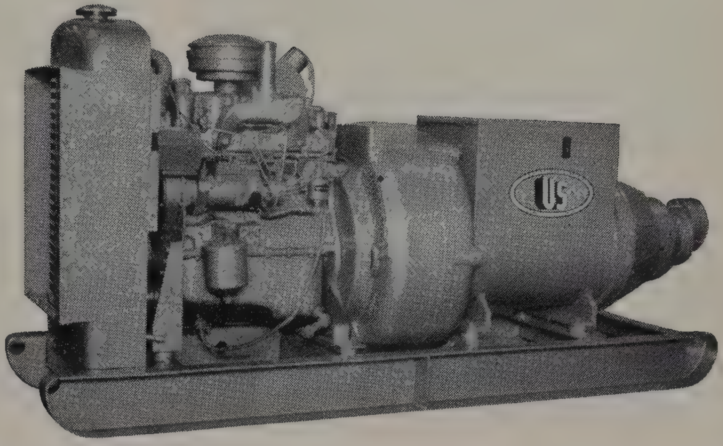

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(Continued from page 114)

above, I do not think this question is pertinent to my editorial, it is an interesting one. As you indicate, group theory has been important in quantum mechanics. Since electronic problems are often analogous to quantum mechanical ones, there is at least some likelihood that group theory can be quite significant to various aspects of microwave theory.

I may say that I have had a hunch for some time that this may be so. Since the days are limited, I have not done anything about it, but it would be interesting to explore the possibility further. At the present time all I can say is, if you can make this application, go to it.

As a final word, it is evident that microwave electronics is making increasing and increasingly deep use of many of the more sophisticated—and esoteric—branches of mathematics. Abstract matrix algebra and group theory are the ones of concern here and now, but it would evidently be dangerous in the extreme to write off any such discipline for even the not-very-distant future.

Yours very truly,
Marshall C. Pease

—*mwj*—

---

Editor, *the microwave journal*
1330 Beacon Street
Brookline 46, Massachusetts

Dear Mr. Saad:

Congratulations on your editorial in the May 1961 issue of *the microwave journal*. You have touched on my "pet peeve," as this situation has been bothering me for many years. If you ask me, off the record, any "lag" behind the Russians which may exist in our program, is principally due to this business of contract negotiations, including the present requirement for quoting definite time, funds and scope on research contracts, which really can't be predicted. I once made a study, for the Department of Defense, comparing our present method of doing business with that employed by OSRD during the war when practically no contract quotations were made or contract controls exercised after award. Using selected items of equipment which I knew about, I found that OSRD did the job more than three times as fast: and, strange to say, their costs per unit produced were less than one-third as great, in spite of all the management or controls employed since the war. I developed a final index, in terms of the number of units produced per million dollars of research money spent, per year of research effort; and it turned out that OSRD was about ten times as effective on this basis. This couldn't all have been due to the extra pressure and urgency which existed during the war.

It also turns out that, if it takes eight years to get an idea through research, development and product engineering, into production (which it usually does), four of those years are expended in bidding on and negotiating contracts.

Also, did you ever stop to think that if nine out of ten contract proposals prepared by our scientific and engineering manpower fail to win an award, and if our professional personnel are spending about one-half their time in writing contract proposals, 45 per cent of our available scientific effort is being wasted on the contract end of the business. I doubt if these are accurate statistics, but the lost motion must be high under any conditions. And think of the effect on the overhead rates and on the cost of the program: all of this time expended in writing rejected contract proposals is charged to overhead. How about starting a crusade? I warn you that it will be very unpopular in certain circles.

Very truly yours,
Donald B. Harris

—*mwj*—

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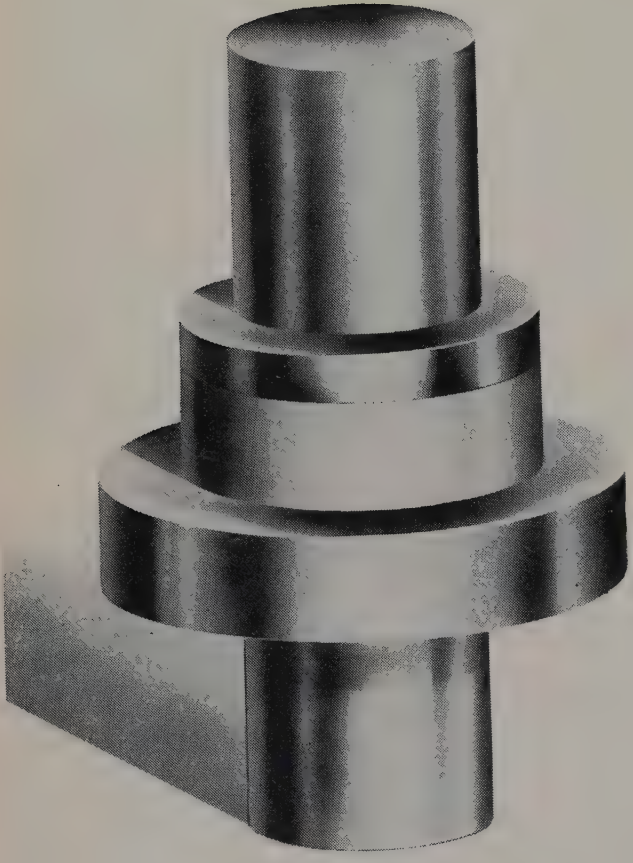

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|---|---|---|---|---|---|---|
| kmc min. | | Rs ohms max. | | Rs ohms max. | | Rs ohms max. |
| 10 | | | MS2620 | 5.0 | MS2630 | 2.5 |
| 20 | | | MS2621 | 2.5 | MS2631 | 1.3 |
| 40 | MS2602 | 15 | MS2622 | 1.3 | MS2632 | 1.0 |
| 60 | MS2603 | 12 | MS2623 | 1.0 | | |
| 80 | MS2604 | 10 | | | | |
| 100 | MS2605 | 8 | | | | |
| 120 | MS2606 | 6 | | | | |

Maximum reverse current 10 μa @ — 30v
Package capacitance typically 0.35 μμf
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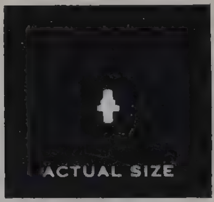

ACTUAL SIZE

| Type | $f_{co}$ @—2v min. | @—6v min. | $C_j$ Zero Bias min. | max. |
|---|---|---|---|---|
| MS2501 | 60 kmc | 80 kmc | 0.2 | 1.1 μμf |
| MS2502 | 80 | 105 | 0.2 | 1.1 |
| MS2503 | 100 | 133 | 0.2 | 1.1 |
| MS2504 | 120 | 160 | 0.2 | 1.1 |
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(Continued from page 112)

## TELEMETRY TRANSMITTER DEVELOPED BY DUKANE

A small, all solid state, crystal controlled telemetry transmitter (FM-CW) developed by the DuKane Corp., St. Charles, Ill., manufacturer of electronic and electromechanical equipment, is now being used successfully in telemetry and tracking operations. The transmitter, the DuKane N15A125 is only five feet x five feet x 1 7/8 inches and weighs less than 20 ounces, including potting.

All conducting surfaces are of silver-plated aluminum and the units are completely transistorized, using only commercially available transistors and diodes. The transmitter is designed to withstand extreme conditions of shock, vibration and temperature.

General specifications of the unit are: size: five feet x five feet x 1 7/8 inches; weight: 20 oz.; supply: 20-24 volts; frequency: 135 Mc band; output: 500 mw-20v, 1000mw-24v; efficiency: 30 per cent; operation temperature: 0°C to 50°C; temperature stability: one part in 10-6 for 5/5°C increment.

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—*m w j*—

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Technical Research Group, Inc., Antenna and Microwave Departments, Somerville, Mass., announces the 897 series of millimeter switchable linear-circular polarized feed horns. The new series is designed for use with paraboloidal reflectors having a 0.3 f/d ratio. The three models available are for use at 3.2, 4, and 8.6 mm.

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—*m w j*—

(Continued on page 126)

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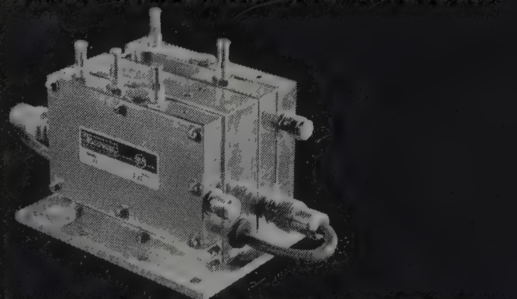

MICROMEGA FM-6 HIGH-POWER VARACTOR MULTIPLIER. Performance characteristics: Input Frequency, tunable from 145 to 165mc; Output Frequency, tunable from 870 to 990mc; Output Bandwidth, 30mc; Multiplication Factor, 3 × 2 = 6; Conversion Efficiency @ 2w input, —7db @ —20db spurious output and —8db @ —60db spurious output; Maximum Input Power, 2w; Operating Temperature Range, —50° C. to +75° C.

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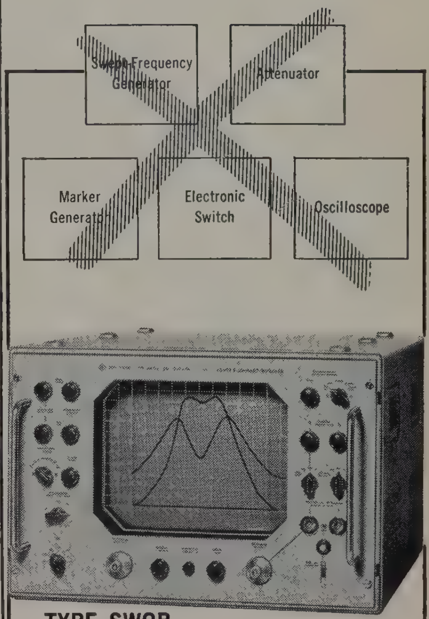

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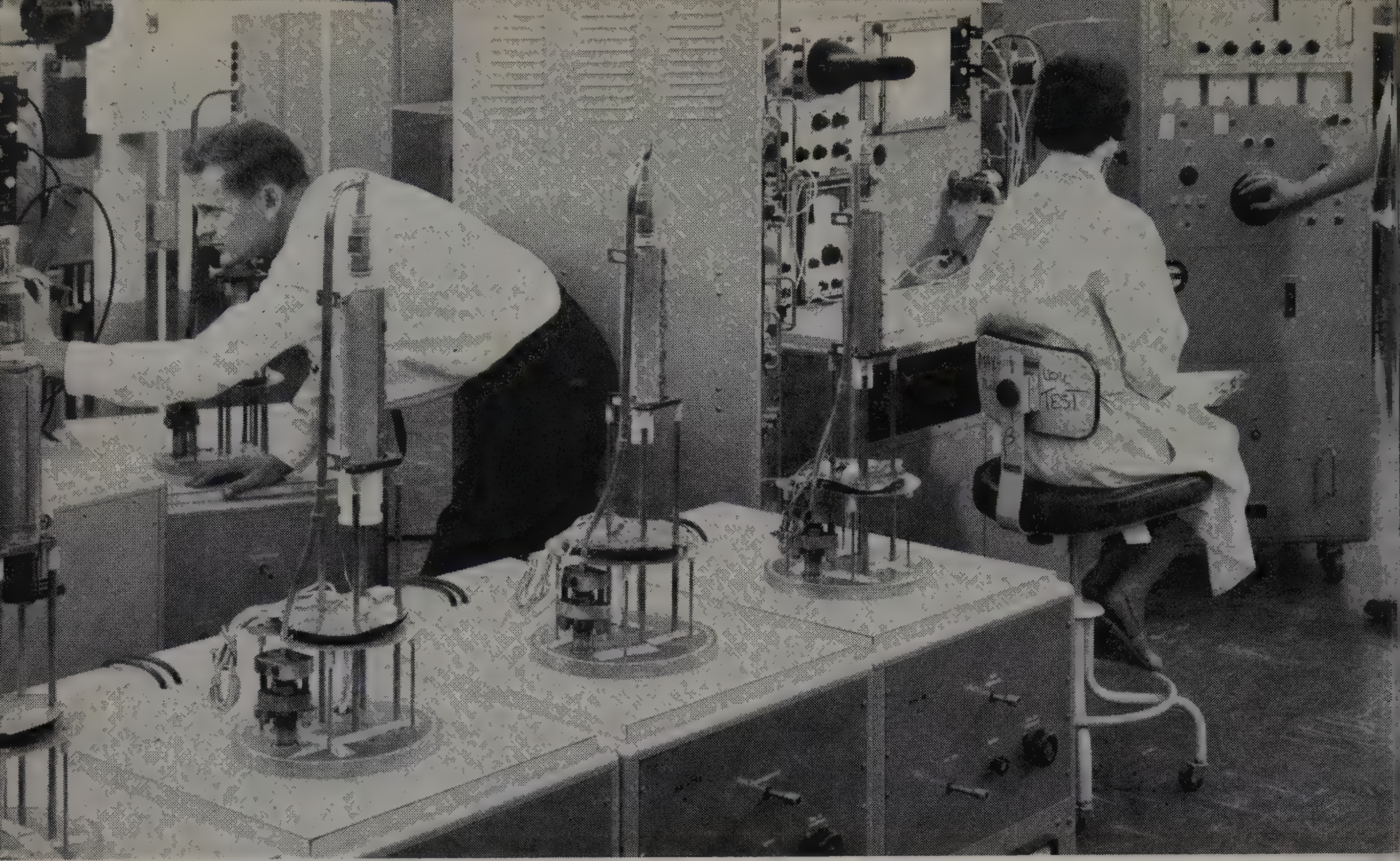


Production testing of metal-ceramic folded waveguide tubes. Pump cart assemblies go through vacuum bakeout and operational tes before seal-off.

## COMPANY PROFILE

# HUGHES AIRCRAFT COMPANY

## *Microwave Tube Division*

### Los Angeles, California

The Microwave Tube Division of the Hughes Aircraft Company is a relative newcomer to the ranks of large volume producers of microwave tubes. Only two years ago, the organizations which combined to form the present Microwave Tube Division had a total yearly sales volume (external to the Hughes Company) of less than three quarters of a million dollars. Today, MTD's annual sales, external to the Hughes Company, are nearing the twelve million dollar level; a growth in less than two years into the ranks of one of the top five suppliers of microwave tubes and one of the top three in traveling-wave tubes.

The story behind this almost unprecedented growth rate in the tube business is an interesting mixture of several factors. First, it is related to a change in the nature of the traveling-wave tube and backward-wave oscillator business from a research phase to a heavy developmen and manufacturing phase. Second, it is a result of th desire of a large group of serious minded young technical people to succeed in a profitable and large busines application of the ideas on which many of them hav been doing research over the past ten years. Third, th growth has resulted from the breaking down of barrier between research, development and manufacturing, wit top people and groups moving through these phase along with their tubes, and returning to the beginnin to start new products at appropriate times.

### Formation of Hughes Microwave Tube Division

The Hughes Microwave Tube Division was formed a the end of 1959 to place in one location all Hughes re search, development and manufacturing related to micr wave tubes. Furthermore, the entire effort was to be under one management with no encumbering ties with other parts of the parent large systems organization. All decisions affecting the daily operation or the long range policy of this division were to be the sole responsibility of the various key people within the division. Included within this autonomous organization were all the required allied functions including marketing, sales, finance, personnel, security, and related activities, which could then be operated at levels enabling the MTD to operate successfully in the highly competitive tube industry.

The technical and productive standards and pace set by its top managers are another key factor in its growth. The management, headed by Dr. L. M. Field, was comprised, from its formation, of scientists and engineers who had demonstrated their capability in this highly complex and specialized area with specific technical accomplishments. As an example, Dr. Field himself is recognized as one of the founders of modern TWT technology, and his many vital patents represent one of the keystones of the industry without which the device would still be a laboratory curiosity.

He and many of the other leaders of the organization came out of research and academic backgrounds but are obviously enjoying themselves tremendously in this rapidly changing world of highly technical production, development and fast-paced business activity.

## Modus Operandi

The conventional functional division of authority and responsibility along such familiar lines as research, development, product refinement, production, quality control and marketing is the antithesis of the Microwave Tube Division's operation. Instead, a constant effort has been made to break down all barriers and distinctions between various groups and activities. Senior engineers, senior research assistants, electronic technicians and other supporting personnel move freely from research to development to pilot production depending on the status of their projects. With these people move the ideas, techniques and enthusiasm which are so essential to the success of any complicated undertaking. Each man learns to appreciate the problems of his counterpart in another phase of the activity and thereby is better able to understand his own responsibilities. New methods of problem solving are perforce exchanged in the process and thereby the debilitating effects of stereotyped thinking are circumvented. Most important, a keen sense of cooperation and esprit de corps is fostered which is very conducive to a healthy productive atmosphere.

## Staff and Facilities

This rapidly growing enterprise, now numbers about 00 people housed in adjacent buildings totalling over 00,000 square feet. Within this air-conditioned area is contained nearly 4 million dollars worth of highly specialized equipment for the development and manufacture of microwave tubes. Included in this array are such items as two dozen high temperature hydrogen furnaces, rf brazing systems, vacuum bakeout ovens, several dozens of high voltage modulators, leak detectors, assemblylines, pump-lines, complete glass facilities, ceramics production and a well-stocked rf testing facility for making "cold" and "hot" measurements of circuit sections, matching subassemblies, and completed tubes. In the R and D Department each individual project has its own array of equipment such as swept signal generators and impedance reflectometers for almost complete independence, allowing maximum utilization of the engineers' time on the tough technical problems.

Dr. W. H. Christoffers, formerly of the University of Illinois and Bell Telephone Laboratories, heads the Manufacturing area, which is staffed, as of June 1961, with 243 engineers, technicians and production personnel. From 1955 to 1959 Dr. Christoffers was a key man in the R and D Department where he had responsibility for many of the tubes now in Manufacturing. This is one example of the close ties between the R and D and Manufacturing areas which characterize the whole organization. The assistant head of the Manufacturing Department, Dr. William M. Mueller, was responsible for much of the early research in backward-wave oscillators and low-noise traveling-wave tubes in the Hughes general research area. At present, he is in charge of the production of a series of helix-type traveling-wave tubes and backward-wave oscillators which constitute two of the Division's major product lines, while continuing his development interests in new types of oscillators.

Heading the low and medium power tube section in the Manufacturing Department is Robert E. Manfredi who came to Hughes from the General Electric Company two and a half years ago with over ten years' experience in tube development and production engineering. B. D. McNary, who also joined Hughes about two and a half years ago, is head of the high power traveling-wave tube section. He has had extensive experience in the development and production of microwave tubes at the General

Dr. Field lectures on the problems of designing high efficiency tubes.

Left to right are the senior management team of the Microwave Tube Division, Dr. J. T. Mendel, Dr. L. M. Field, W. E. Trantham, Jr., Dr. W. H. Christoffers, and C. L. Flores.

Electric Company and the Federal Telecommunications Laboratories.

The R and D Department of approximately 135 people is comprised of 26 engineers, 38 research assistants, and associate engineers along with supporting groups of draftsmen, electronic technicians and precision machinists. The large majority of the engineers possess either masters or PhD degrees in electrical engineering or physics and most of the research assistants have had several years of formal college technical training. The department is headed by Dr. J. T. Mendel, formerly of the Bell Telephone Laboratories, where he was associated with Dr. J. R. Pierce during the pioneering period in traveling-wave tubes and periodic focusing of electron beams.

Allan W. Scott, assistant head of the R and D Department, also an alumnus of Bell, received his education at Stanford University and the California Institute of Technology. Mr. Scott's background at Cal Tech is quite typical of the department since many of the graduate students at this school eventually come to work for the division because of the close technical ties between the two establishments. Several members of the Microwave Tube Division have been faculty members of the graduate school of engineering at Cal Tech, and many of the graduate students have been given financial support through Hughes scholarship grants.

Dr. D. J. Bates and Bruce A. Highstrete are the two major section heads in the R and D area and have both been with the Hughes Aircraft Company for about years, following their graduate studies at Stanford and M.I.T. respectively. They were part of the key research team which launched the company in the high-powered TWT business at a time when the activity at Hughes was one of the few such efforts in the entire country.

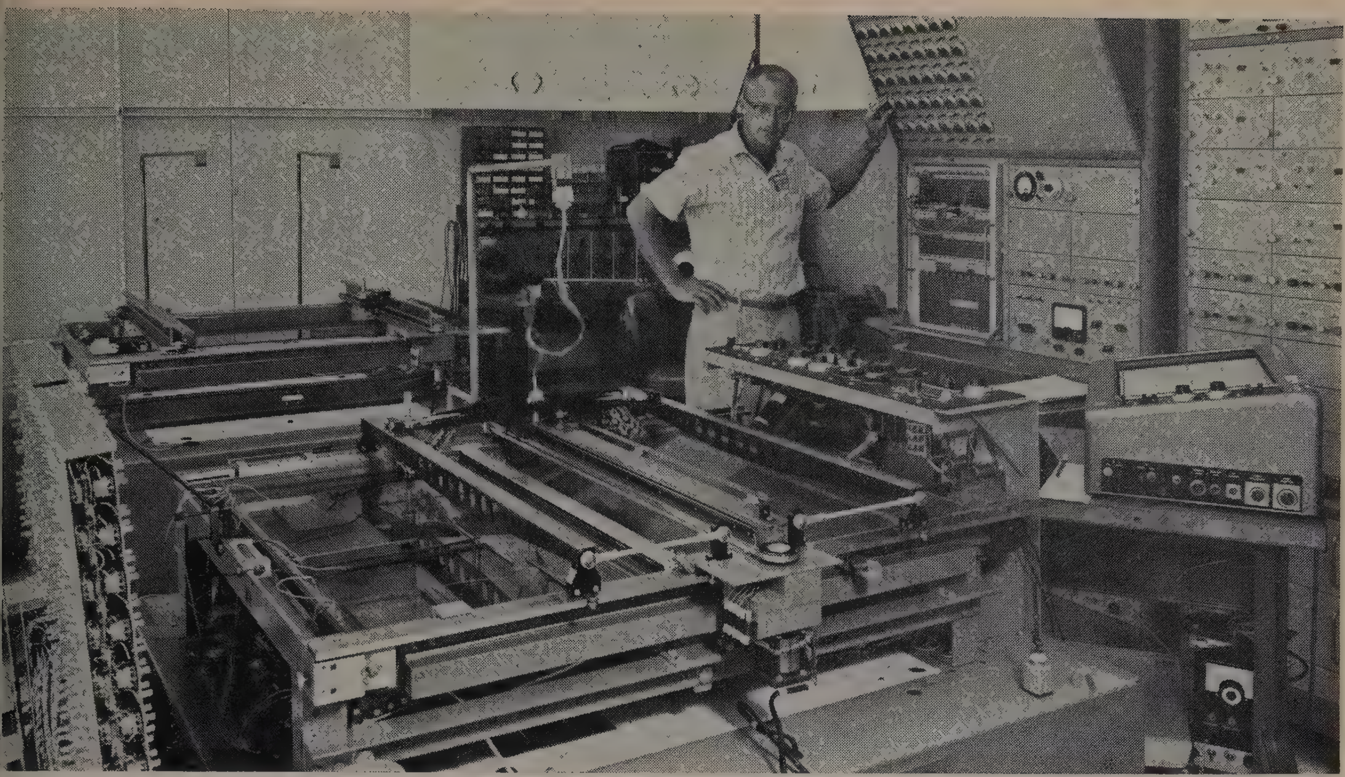
## History

Electronics is the major interest of the Hughes Aircraft Company. The company's research and development capability in electronics is internationally known; and it tries to keep its systems design groups among the world's best. In order to maintain technical leadership, Hughes considers it necessary to provide its scientists and engineers with fine laboratory facilities and the most advanced component parts. As a result, Hughes has established many excellent research laboratories.

It was with this concept that the Electron Tube Laboratory was conceived in 1948. Its function was to make known and available to the Hughes systems groups the most modern microwave tube and direct display tube components, and to produce them internally, if necessary. Initially, the laboratory performed only very basic research; later, the researches led to specific devices under the technical direction of Dr. Field, then associate director of the Hughes Research Laboratories.

While his responsibilities were far more encompassing than microwave tubes, his interest in these devices was deep rooted. In earlier years at Bell Telephone Laboratories, he had collaborated with Dr. J. R. Pierce as co-developer of the first stable traveling-wave tube. Later as Professor of Electrical Engineering at Stanford, he invented many modern forms of traveling-wave tube propagating structures. Concurrently with his consulting association with Hughes, he was appointed to the position of Professor of Electrical Engineering at the California Institute of Technology where he also established a tube research activity.

Ferrite magnet stacks are individually tested on automatic recorders and records kept with each tube.



Coupled electrolytic tanks for magnetic and electric fields, including space charge, run by analog computer to give detailed electron trajectories. This is used in the design of high-perveance, high-convergence, low aberration guns and focusing systems.

Under Dr. Pierce's direction at Hughes, such devices as the resistance wall, rippled stream, velocity jump and impedance wall amplifiers were developed. These developments were followed by a normal progression into specific traveling-wave tube types, of which the backward-wave oscillator became one of the first major interests of the laboratory, and Hughes developed a number of tubes and packages which have led to an extensive oscillator manufacturing business.

Although the developmental aspects were subordinate to those of research, several noteworthy inventions of a highly practical nature distinguished this early effort. Dr. M. R. Currie and his co-workers established a record in low noise amplification for a TWT by exploiting a new principle which was discovered in the course of their fundamental noise investigations.

The company's activities in airborne radar applications brought to light a need for developing power tubes which would be capable of producing very high power and large bandwidths. Extensive studies were made of nonlinear behavior, ways of preventing self-oscillation, and methods for designing and producing efficient electron guns of smaller size with higher current at lesser voltage and lower aberration. The process was long and slow, but the results were gratifying.

Dr. G. R. Brewer organized the first truly systematic approach to the study of electron beam formation and control which led to several classic papers on this vital subject. From a practical viewpoint the result of this exhaustive electron gun research program has been the development of a series of gridded and ungridded guns extending the power capability of many TWT devices by a factor of ten or more. It is well known that the optical perfection of the beam forming and control mechanism is one of the key limitations in producing large amounts of average rf power.

The most popular and widely used filter-type TWT circuit was invented and developed at Hughes in 1954-55. During the course of investigating possible circuits for high-powered TWT's, Dr. L. M. Field and Dr. R. Gould devised the "folded waveguide" circuit which was later refined to its circular symmetric form known as the "coupled cavity circuit." Today, all leading microwave tube manufacturers employ variations of this basic circuit because of its natural simplicity and excellent electrical properties.

Perhaps the most profound and exciting development of the pioneering activity at Hughes was the adaptation of periodic magnetic focusing to power TWT's. When PPM focusing was invented and first demonstrated at Bell Laboratories, an effort in which MTD's manager of R&D, Dr. J. T. Mendel, was extensively involved, its fundamental limitations were then thought to be so restrictive that it could only be utilized in small signal devices where the beam power density is typically quite low. However, the real need for this lightweight focusing method existed at the high power levels where TWT's (with focusing solenoids) were prohibitively large and weighty. By a combination of the focusing structure and the rf circuit which allowed the magnetic field to be introduced very near the beam periphery, Hughes investigators opened up some new possibilities for the application of periodic focusing. With the breakthrough came a new class of power TWT's which were so compact and light that even airborne restrictions on size and weight were satisfied. Fifty per cent of the current manufacturing business of the Microwave Tube Division would not exist were it not for this crucial development in beam focusing.

### Present Activity in Manufacturing

Few organizations have experienced the phenomenal growth rate of the Microwave Tube Division's manufacturing area since its establishment in late 1959. Starting in January, 1960, with a backlog of less than $200,000, the manufacturing area sales in one and one-half years has grown from a three-quarter million to near the $10,000,000 per year volume booking rate. Prior to 1960, its customers were almost entirely other Hughes divisions who desired small quantites of tubes for breadboard applications and service test set evaluation programs, while today most of the large volume demand is from outside companies. In January, 1960, the Manufacturing Department was a skeleton group with only a minus record of accomplishment. During the following year the group grew to a 300 man complement which shipped more than 1000 tubes during this period of growth. At the present level, the number of shipments should approach the 3000 level even though many of the devices making up this total were not even in the manufacturing catalog one year ago.

Currently, the largest volume of manufacturing business is in high power gridded traveling-wave tubes for countermeasure applications in the major radar frequency bands. This includes a family of periodic permanent magnet focused, helix-type traveling-wave tubes. Several of these tube types have been qualified to meet MIL-E-5400D specifications.

Other types of tubes which have found wide applications in the countermeasure field employ a new broadband version of the coupled cavity circuit which was first publicly described by the R and D group of the MTD just one year ago. Such a rapid transition from research to manufacturing is not uncommon in this rapidly changing industry.

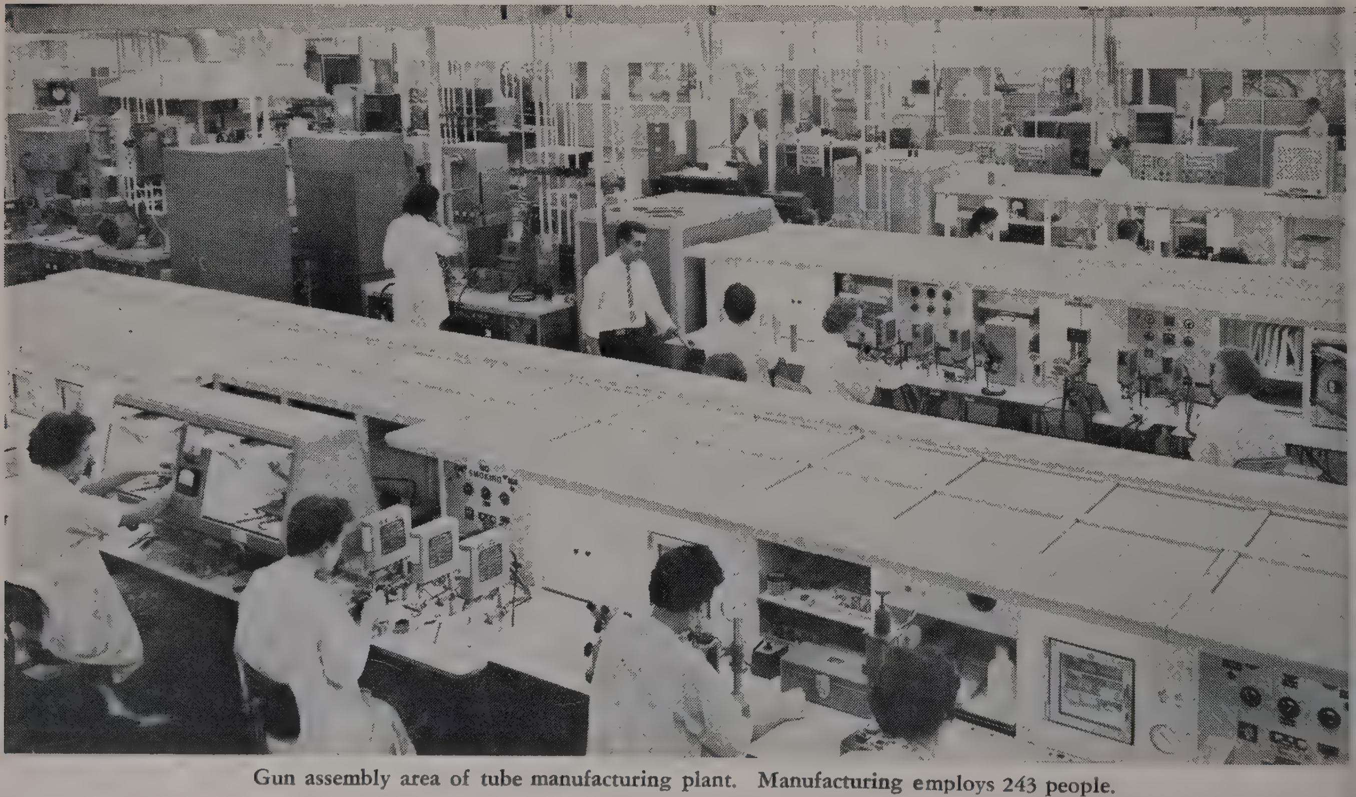
Another big manufacturing item is a series of permanent magnet focused backward-wave oscillators for the vital NIKE defense system produced by the Western Electric Company. The exacting requirements of this system were well satisfied by a device which had a long history at Hughes dating back to 1951, just after the revolutionary electronic oscillator was invented at CSF and Bell Telephone Laboratories. This series of backward-wave oscillators has been extended to cover many other frequency ranges.

Although currently made in pilot quantities, an increasingly important tube is a 50 kw X-band high gain PPM focused device which serves as a single tube radar for CHIRP-type systems. The gain of this tube is such that the output from existing low powered oscillators at the 10 milliwatt level can be amplified to the 50-100 kw level in a single broadband device weighing about 20 pounds.

Another tube in pilot production is a high gain PPM focused 15 kw tube at X-band which has a high mu grid control for phased array applications. Techniques are being evolved whereby the critical electrical parameters of these tubes are precisely predictable and reproducible so that large quantities of electrically identical tubes can be made economically.

### R and D Activity

In the R and D area the heavy emphasis is on high powered cw tubes at C- and X-band for communications and countermeasure systems. These devices are being designed to operate at the 2 to 10 kilowatt level with bandwidths from 10-35%. Broadband fm transmitters for ground-to-satellite communication purposes have outgrown the bandwidth limitations of klystrons at this power level and yet the required bandwidth of several hundred megacycles is well below the capability of most TWT's.



Gun assembly area of tube manufacturing plant. Manufacturing employs 243 people.

The Microwave Tube Division in Los Angeles, California.

Along these same lines considerable effort has been devoted to the development of extremely lightweight TWTs for use as transmitters inside active communication satellites. Efficiency and reliability are the primary requirements along with a rugged construction capable of withstanding the launching shock and vibration environment. One such tube, a 8 $\frac{1}{2}$ ounce, 2000 Mc helix-type 2.5 watt metal-ceramic device has been successfully demonstrated and similar tubes at 4000 Mc are currently under development. These same devices have all the necessary attributes for telemetry use and also might find application in small decoy-type missiles.

Because of many unusual characteristics of the mm-wave region, the military interests in this band are quite keen. Many of the circuit and beam techniques which proved highly successful at X-band are now being extended to the 50 kMc region to accommodate future systems needs.

### Future Emphasis

New areas for research and development appear constantly as new systems needs occur. MTD's present major efforts are along the following lines:

a) Methods of substantially improving the electronic efficiency of TWTs are being studied. Whereas in the past it has been common practice to sacrifice efficiency in order to achieve improved stability and freedom from oscillations, this is no longer essential in view of the newer techniques for suppressing oscillations.

b) The average power capability of TWT circuits and gridded guns are being constantly increased so that these devices will keep pace with the present trend of systems. To accomplish this is not easy since it involves better beam focusing and the design of circuits with basically better thermal properties while not sacrificing the electrical characteristics so vital to high efficiency.

c) Quantity production techniques are being improved for the highly complex coupled-cavity tubes which now represent a major fraction of the manufacturing business. This means far more than just devising efficient tooling; for the real improvements are to be realized by upgrading the product and thereby greatly enhancing the yield rate. Thus substantial economies can be achieved which will result in more attractive prices for these important new components.

d) A better and more fundamental understanding is required of the major factors affecting quality control. What seems to be necessary is a continuing program of product evaluation by the very same engineers and scientists who were responsible for its evolution, including research and development of new materials for electron emission, heat conduction and insulation.

### Finance, Marketing Service Functions

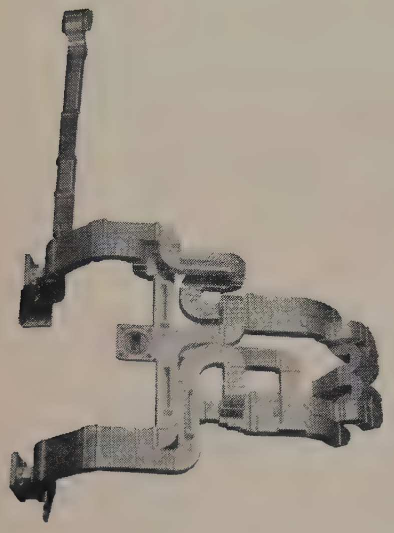
A considerable share of the credit for the rapid, stable growth is a reflection of excellent relations between the technical areas and the business organization.

W. Earl Trantham manages both marketing and business services and Carl Flores heads the finance area. Both of these men have technical as well as business backgrounds. There exists an excellent rapport between the engineers and these men and their representatives, to a degree which is not often found in industry. As a result, there is a continual flow of information on bidding, technical liaison with customers, analyses of cost of parts and labor and possible cost reductions, profitable and unprofitable operations, and overhead. Project heads and many of their engineers have become not only conscious of these factors, but also leaders in steps to effect a more efficient business. Groups at lunch, and in after hours personal friendships, reflect an interesting mixture of R and D, Manufacturing, Finance, Marketing and Management, showing a healthy absence of barriers between groups.

Above all, the Finance, Marketing and service organizations, as well as the management, consider this to be primarily a technical organization. These areas work for the technical people and not vice-versa, either in principle, practice or feeling, as is so often the case. As a result, the engineers work cooperatively with them, service is rapid and overhead is relatively low.

With the present interesting spirit of cooperation between these areas and the tremendous competitive drive and zeal that now permeates the organization, continued healthy growth of the MTD appears extremely likely.

# DIP BRAZING
## for fabricating complex components



Microwave component for Convair, A Division of General Dynamics Corporation. Produced by assembling and dip brazing 109 separate pieces of aluminum extrusions, castings or machined parts. Tolerances are ±.002. Overall length is 13″. ASSEMBLED AND DIP BRAZED FOR QUALITY ASSURANCE BY PRECISION DIPBRAZE, INC.

**Dip Brazing** permits low cost fabrication of complex assemblies made up of numerous individual aluminum extrusions, castings, forgings or machined pieces. The DIP BRAZE method yields greater strength, neater joints, and as there is less distortion or warpage during the brazing process, close tolerances can be maintained.

**Complete Dip Brazing Service.**

**PRECISION DIPBRAZE, INC.** provides complete dip brazing services for producing quality assured waveguide assemblies, missile engine components, electronic chassis, heat exchangers, and a wide range of hardware used in the aero-space, ground support, communications and commercial fields. Precision machine shop facilities are maintained to support manufacturing and fabrication services.

Technical assistance on assembly, joint design and brazing is provided.

**Write for Technical Bulletin PDI 2**

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## New Products

*(Continued from page 119)*

### SEMI-FLEXIBLE CABLE CONSTRUCTED BY PRODELIN

Prodelin, Inc., Kearny, N. J., designers and manufacturers of antennas and transmission line systems, is now producing a new foam polyethylene insulated, aluminum sheathed, coaxial transmission line called Spir-O-foam. Especially designed for low-loss broadband performance, this semi-flexible cable, with its matched Spir-O-lok companion connector, provides a reliable, job-packaged combination with simple installation features.

Spir-O-foam effects new economies in broadband communication applications by its unlimited operating life, complete rf shielding and elimination of pressurizing. This new Prodelin cable offers many features including no connector pin "pull-out" and clearly marked sheaths for easy length measurements and cable identification. Supplied on non-returnable reels at no extra charge, Spir-O-foam is available in continuous lengths up to 1000 feet.

Prodelin Spir-O-lok connectors are electrically matched to the new Spir-O-foam cable. These connectors are backed by years of service-proved features providing simple field assembly without special tools and economical maintenance-free service.

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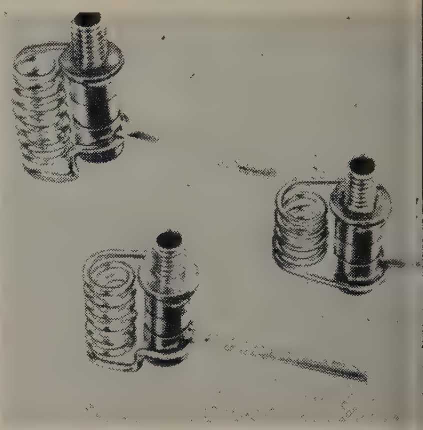
### SERIES OF TANK CIRCUITS DEVELOPED



JFD Electronics Corp., Brooklyn, N. Y has developed a new series of tank circuit offering, in a very small physical size, very wide tuning range.

The basic unit consists of a precision miniature piston capacitor, the VC20G across which an air core coil is soldered. The number of turns of the coil determines the range of the unit.

Five standard units are available — LC 371 with a self resonant frequency variable between 475 and 1000 Mc; LC 37 with a self resonant frequency variabl

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**COAXIAL MICROWAVE TERMINATIONS**

ALL COMMON CONNECTOR TYPES

Lower Microwave
0-3000 Mc
1.05 VSWR

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1.05 VSWR

Sliding Terminations for Calibration Purposes — in the Range 500 Mc-12000 Mc

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TNC
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BNC
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Perpetual, in-the-house Development Programs make R-D-C the Microwave Industry's *most versatile* supplier of SPECIAL and STANDARD Coaxial Components:

- ABSORBERS
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- ATTENUATORS
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GLenview 4-4418
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between 290 and 850 Mc; LC 373 with a self resonant frequency variable between 230 and 650 Mc; LC 374 with a self resonant frequency variable between 190 and 525 Mc; and LC 375 with a self resonant frequency variable between 165 and 425 Mc.

The nominal Q of these coils is in excess of 230 (measurements are made at frequencies between 80 and 220 Mc.)

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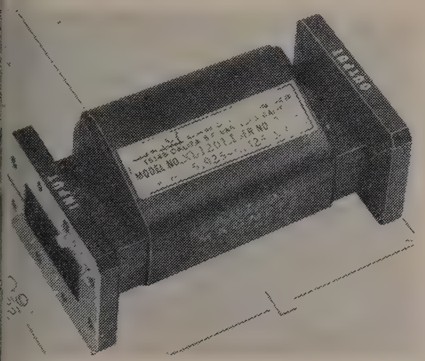
### SERIES OF C-BAND ISOLATORS OFFERED BY E&M

E&M Laboratories, Van Nuys, Cal., announces the development of 24 isolators specifically tailored for the commercial frequency ranges in C-band. These C-band isolators are extremely light in weight and exhibit superior electrical characteristics.

The variety of components in this series permits selection of standard units ranging in lengths from 2.1 inches to 4.5 inches as well as a choice of isolation and insertion loss characteristics. All of the isolators are bilaterally matched with a maximum VSWR in the forward and reverse directions of 1.10.



Typical midband isolation: insertion loss ratios range above 60:1. Single unit price is $150.00 and quantity prices will be quoted on request.

**Circle Reader Service Card 134**

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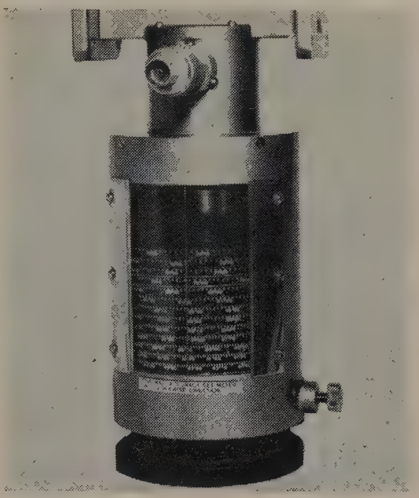
### FXR MARKETS DIRECT READING FREQUENCY METER

Details on a special resolution waveguide frequency meter for use in the 7.5 to 9.6 Gc range have been disclosed by FXR, a division of Amphenol-Borg Electronics Corp., Woodside, N. Y.

Known as the Model S60-13, this meter offers continuous high resolution over the entire frequency range with one Mc as the least dial division. Accuracy of ±1 Mc is maintained throughout the temperature range of from +32° to +85°F.

FXR's model S60-13 is a three-terminal frequency meter. At resonance there is a nominal dip of 20 per cent in the power level on the main waveguide. Simultaneously, a signal 20 db down from the level in the main waveguide is fed to a coaxial crystal mount coupled to the resonant cavity. Frequency readings are taken directly from the high resolution spiral scale.

The meter derives its high accuracy through use of a high Q (8,000 approx.) resonant cavity tuned by a non-contacting choke plunger. A precision lead screw drives the tuning plunger and the spiral frequency scale simultaneously.



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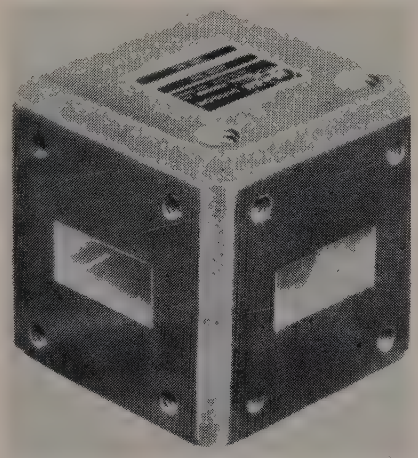
### THREE-PORT CIRCULATOR INTRODUCED BY KEARFOTT

A new high-power broadband three-port circulator is being marketed by Kearfott Microwave Division, General Precision, Inc., Van Nuys, Cal., manufacturers of precision microwave components and test equipment.

The new circulator may be converted into a microwave switch by replacing the permanent magnet with an electromagnet. Models with power handling capabilities of 50 kw or more are available on request.

Outstanding features of the new three-port circulator are: frequency range: 8.0 - 10.5 kMc; isolation: 20 db minimum; insertion loss: 0.4 db maximum; VSWR: 1.20 maximum; power: 25 kw peak 25 watts average; connectors: mate with UG/39/U.



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READ

RF FREQUENCIES TO ±0.03%

WITHOUT TABLES

NOW you can get direct-reading convenience **plus** extreme precision of tuning **plus** broad frequency coverage . . . **without using tables or calibration charts.**

Only DATA-DIAL (patented) direct-reading wavemeters bring you these advantages. The tuning knob drives a long tape carrying a sloped frequency scale, which moves behind an index curve accurately drawn on a transparent window. As the cavity is tuned, the moving intersection point of these curves compensates for inherent variations, giving the frequency for each setting without further correction.

Model 3102 covers frequencies from 900 to 2100 mc, with a direct-reading accuracy of ±0.03% below 1700 mc and ±0.05% above that point. The cavity has an integral crystal detector output. Model 3103, in final development, covers frequencies from 2350 to 3750 mc. Other models will extend the range of this new line to further bands.

WRITE TODAY for more information on this and other new GCC developments in microwave components, pulse power calibrators, attenuators, oscillators and test sets.

GENERAL COMMUNICATION COMPANY
677 Beacon Street
Boston, Mass.

*SEE US IN BOOTH 4302 AT WESCON!*

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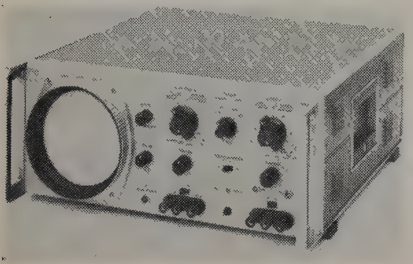
# BOOTH INFORMATION

### HEWLETT-PACKARD CO.
### BOOTHS 2313-16 AND 2318



Over 35 new instruments and systems for making precise, time-saving electronic measurements will be exhibited by Hewlett-Packard Co., Palo Alto, Cal., at the 1961 WESCON Show.

Featured in the exhibit will be 22 instruments presented in Hewlett-Packard's new modular enclosures. These compact, modular units represent a completely new concept in instrument packaging, one which enhances the appearance of the instrument and increases its operating convenience and versatility. The modular instruments may be used as either bench or rack models, and may easily be incorporated into complete, space-saving measuring systems.

**Circle Reader Service Card 137**

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### HUGGINS LABORATORIES, INC.
### BOOTHS 2308-10

A new periodic permanent magnet focused, low-noise traveling wave tube will be introduced at the 1961 WESCON Show by Huggins Laboratories, Inc., Sunnyvale, Cal.

Designated the HA-60, the TWT exhibits the following electrical characteristics across the eight to 11 kMc frequency range: 17 db maximum noise figure, 25 db minimum, small-signal gain, and 10 mw minimum saturation power output. When operated more broadband, from 7 to 11 kMc, the HA-60 achieves 30 db minimum small-signal gain and 20 db maximum noise figure, with 10 mw minimum saturation power output.

The HA-60 is compactly designed, and all rf and dc connections are placed for ease of accessibility. The tube requires 106 cubic inches of mounting space, weighs 4 3/4 pounds, and requires no focusing solenoid or solenoid power supply.

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### ESC ELECTRONICS CORP.

Included in the new product lines that will be exhibited at WESCON by ESC Electronics Corp., Palisades Park, N. J., is a newly developed transponder delay line designed to meet critical weight and space requirements in air traffic controls, radar, and airborne equipment. The line features a 40 to one relay rise time ratio in a six cubic inch case.

Also to be shown is a new line of miniaturized low pass and high pass filters with an attenuation of less than three db at cut off frequency; and the first in a new series of miniature delay lines, Model 37-34, which features better than 35 to one delay/rise time ratio and a low attenuation of two db with high temperature operation of −55°C. to +125°C.

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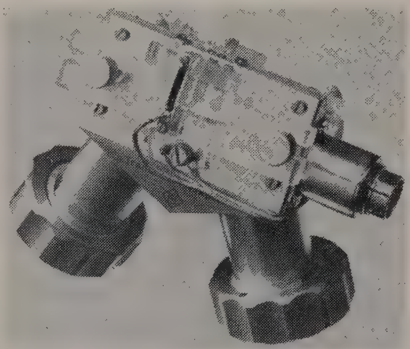
### ROHDE & SCHWARZ
### BOOTHS 2526-28



Included in the extensive line of Rohde & Schwarz Co., Passaic, N. J., measuring instruments to be exhibited at the WESCON Show is a new Transistor Adaptor and Accessories, Model BN 35616, to be used in connection with the company's Z-g Diagraphs, Types ZDU, ZDD or coaxial slotted lines.

The Transistor Adaptor has a frequency range of 30 - 3000 Mc and, with the use of accessories, may be modified for ranges of 30 - 1000 Mc and 300 - 3000 Mc.

The small dimensions of coaxial connectors on modern day high frequency transistors preclude the usual impedance or admittance measuring devices. With the use of the new Transistor Adaptor, the diameter of connections is reduced to three mm, while still maintaining the characteristic impedance of the coaxial feed lines. Consequently, electrical characteristics up to 3000 Mc are possible.

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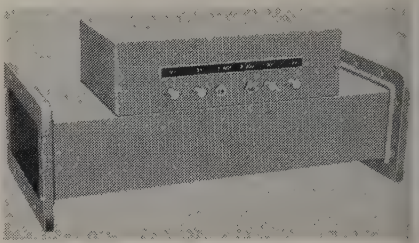
### DIELECTRIC PRODUCTS ENGINEERING CO.
### BOOTH 4411



At 1961 WESCON, Dielectric Products Engineering Co., Raymond, Me., will display and release details on a line of waveguide resolvers which provide instantaneous CRT Smith Chart display of reflection coefficient as a continuous function of frequency in the range 350 - 12,000 Mc/s.

The resolver, in conjunction with an oscilloscope and swept signal generator, provides an oscilloscope trace on a Smith Chart faceplate which may be directly photographed for permanent recording, or an X-Y chart recorder can be used. VSWR uncertainty is 1.01. The faceplate is rotatable in order to refer the impedance plot to any point along the transmission line.

**Circle Reader Service Card 141**

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### FILMOHM CORP.

Filmohm Corp., New York, N. Y., will exhibit a new addition to its line of coaxial termination resistors at WESCON. The resistor is a low temperature coefficient pure metal resistance film approximately 20 millionths of an inch thick, fused at elevated temperatures onto a high strength, dense, non porous ceramic form.

The new product is ideally suited for use as a coaxial termination for 3/8 line It is rugged, resistant to shock and vibration and suitable for the most severe environmental conditions. Resistor design permits the use of metal contacts or fingers whose O.D. is identical to the .125 inch O.D. of the inner conductor of the line. Thus, the line inner conductor, metallic contact, and resistor, are all maintained at .125 inch O.D.

When properly mounted in a 3/8 inch with type N connectors, a VSWR of 1.05 from dc to 4000 Mc can be achieved. By the use of suitable impedance matching techniques the frequency range can be extended to 10,000 Mc.

**Circle Reader Service Card 142**

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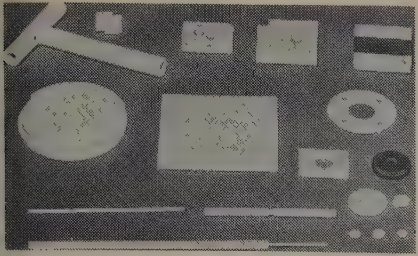
## NATIONAL BERYLLIA CORP.
## BOOTH 4624



Precision machined mounting blocks and other components of beryllium oxide, a unique ceramic electrical insulating material that conducts heat like a metal, are featured in the exhibit of National Beryllia Corp., Haskell, N. J., at the WESCON Show.

Used for mounting electrical components, beryllium oxide shapes insulate them electrically while providing a path for heat flow away from them. This unique ability of beryllium oxide to help cool the components which it insulates enables designers to operate electronic components at lower temperatures or at higher power, and in some cases permits elimination of blowers or other bulky and heavy auxiliary cooling devices.

Available in many off-the-shelf standard shapes, high-purity beryllium oxide ceramics are also custom-produced by National Beryllia, cast, pressed, or extruded to order and machined, when required, to close tolerances. Surfaces can be metallized when required.

The company is also displaying a line of beryllium oxide heat sinks for semiconductor mounting, available off-the-shelf to fit the most popular JEDEC TO outlines.

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## VARIAN ASSOCIATES

Included in the WESCON exhibit of Varian Associates, Palo Alto, Cal., will be several new microwave tubes, an atomic frequency standard, two new automatic high vacuum systems, and dozens of new microwave devices, components and accessories.

Among the microwave tubes displayed will be: the VA-849 which features high CW power at X-band, 20 kw at 7.125-8.5 kMc, ideal for earth-to-satellite communication, radar astronomy, missile illumination and orbital scatter communication; the VA-853 which is a high gain amplifier klystron giving 75 kw, CW output at 755-985 Mc; and the VA-851 which offers 2.5 kw, CW power from 10-10.55 kMc with very low am and fm noise.

Also, the VA-126 with three megawatts peak, five kw average power at 5.4-5.9 kMc; and the VA-244A-B-C which is a series of three reflex klystrons which provide extreme versatility in microwave relay systems, frequency ranges from 5.8-7.9 kMc with average power output of one watt.

**Circle Reader Service Card 144**

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## MICROLAB
## BOOTH 4306

Microlab, Livingston, N. J., will show for the first time several new lines of products including new directional couplers, crystal mixers, and other coaxial products. All of these items are designed for minimum size and weight and are ideal for airborne and other systems applications.

The booth will feature the above items plus a selection from Microlab's standard stock of over 10,000 coaxial components. Available for distribution for the first time will be the new 16 page catalog 10A in which are described the new directional couplers and mixers as well as new five watt attenuators and resistive signal samplers.

This will be the first national show in which Microlab will be participating as an exhibitor since their founding in 1950 and is part of their increased marketing program.

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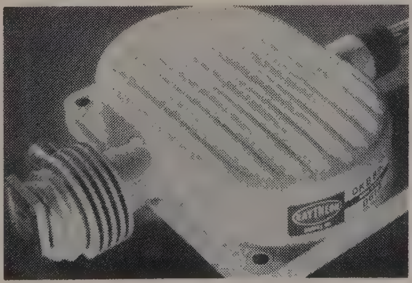
## RAYTHEON MICROWAVE & POWER TUBE DIVISION
## BOOTHS 3410-3412

Two new K-band backward wave oscillators extending frequency coverage to 26.5 kMc will be introduced at WESCON by the Microwave and Power Tube Division, Raytheon Co., Lexington, Mass.

Latest in a line of compatible "O" - type BWO's developed to meet the most severe military requirements, they are the smallest and lightest tubes available in this class.

Frequency range of the QKB890 is 12.4 - 18 kMc, while the QKB891 covers the range from 18 - 26.5 kMc. Both tubes are rated at 20 milliwatts minimum output power, and have a control grid for low-voltage pulsed applications. Both feature permanent magnet focusing, and may be mounted with a spacing of only two inches between tubes.



Small size, all metal-ceramic construction, and long life make these tubes ideal for use as swept local oscillators in space, airborne, and ground-based receivers and test equipment. High power output also makes them suitable as pump tubes for parametric amplifiers, where their tunability enables one tube to be used for several amplifiers at different frequencies.

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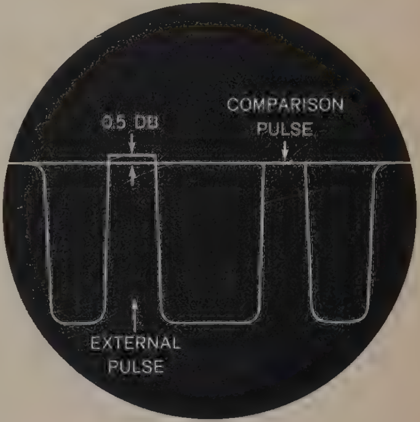
(Continued on page 132)

DETERMINE

PEAK PULSE POWER WITHIN 0.5 DB



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# Abstracts from *Russian Technical Literature* . . . of interest to microwave engineers

*Translations of complete papers can be made available by contacting Morris D. Friedman, Inc., c/o "the microwave journal," 1330 Beacon Street, Brookline Massachusetts. Prices are dependent upon length of paper.*

*ES, 15(1) (1961)*

**F. B. Shteinshleiger:**

### QUANTUM PARAMAGNETIC MICROWAVE AMPLIFIERS. PART II.

*pp. 40-49.*

The physical operating principles of quantum paramagnetic amplifiers were analyzed in the first part. Below, the different kinds of such amplifiers and their noise factors are analyzed.

*(5F, 10R)*

— *m w j* —

*ZTF, 30(7) (1960)*

**B. M. Bulgakov, V. P. Shestopalov, L. A. Shishkin, I. P. Iakimenko:**

### SLOW WAVES IN A HELIX WAVEGUIDE WITH A PLASMA.

*pp. 840-850.*

A dispersion equation is obtained and investigated for a helix mounted in a dielectric tube within which is a plasma in the presence of a permanent magnetic field applied along the system axis.

*KHAR'KOV UNIV. (7F, 6R)*

— *m w j* —

**A. N. Akhiezer:**

### ON THE COUPLING OF RECTANGULAR WAVEGUIDES BY USING AN ORIFICE IN THE WIDE WALL.

*pp. 851-854.*

Formulas with empiric corrections are obtained for the coupling of two waveguides by means of one orifice in the common wide wall for arbitrary wall thickness, orifice diameter and distance between the orifice and the waveguide axis. A comparison is made with experiment in the 3 cm and 8 mm bands for $\frac{d}{\lambda_g} < 0.33$.

The formulas can be used in computing the coupling system of waveguide directional couplers.

*KHAR'KOV INST. OF METERS AND MEASURING DEVICES (2F, 10R)*

— *m w j* —

*ZTF, 30(8) (1960)*

**A. I. Zykov:**

### DIVISION OF AN ELECTRON BEAM AT THE OUTPUT OF A LINEAR ACCELERATOR BY USING AN ELECTROMAGNETIC WAVE IN A WAVEGUIDE.

*pp. 971-974.*

It is sometimes necessary to divide the primary electron beam during a high-frequency pulse into two beams diverging symmetrically from the accelerator axis. . . The proposed method is based on the interaction of electron bunches with a transverse electric mode of $H_{10}$ type in a waveguide for which the frequency is half the frequency of bunch succession and the phase velocity $v_f$ is twice the displacement velocity of the bunches, $v_e$, i.e., the velocity of light, since $v_e \approx c$.

*PHYS.-TECH. INST. AN UKRSSR (3F, 1R)*

— *m w j* —

*ZTF, 30(9) (1960)*

**V. V. Iankov:**

### ON THE STABILIZATION OF LOCALIZED AND FLYING PLASMA BUNCHES BY ELECTROMAGNETIC WAVES.

*pp. 1019-1023.*

The dynamics of an infinitely conducting small spherical plasma bunch in a field of electromagnetic waves excited in cavities and waveguides is investigated.

*FIAN USSR (12R)*

— *m w j* —

**A. I. Tereshchenko:**

### WAVEGUIDE OF "DUMBBELL" CROSS-SECTION.

*pp. 1074-1076.*

The H -shaped waveguide has many advantages and some disadvantages as compared with waveguides of simple shape such as rectangular and circular . . It is expedient to attempt to find a compromise in terms of a new cross-sectional shape. Such a shape, which is a modification of the H -waveguide, we shall designate a "dumbbell."

*KHAR'KOV UNIV. (2F, 5R)*

— *m w j* —

*ZTF, 30(11) (1960)*

**V. E. Golant:**

### MICROWAVE METHODS OF INVESTIGATING PLASMAS.

*pp. 1265-1320.*

Results are explained in section 1 of research in which expressions have been obtained to determine the relation between plasma characteristics and the conductivity for various cases. . . The theoretical basis of methods of investigating plasmas (cavity, waveguide and free-space) and their application are analyzed in sections 2, 3 and 5. . . The use of a microwave field to heat a plasma during investigation by the cavity or waveguide method is analyzed in section 4.

*LENINGRAD PHYS.-TECH. INST. AN USSR (22F, 5T, 96R)*

— *m w j* —

*ZTF, 31(1) (1961)*

**V. E. Golant, A. P. Zhilinskii, M. V. Krivosheev, G. P. Nekrutkina:**

### CENTIMETER WAVE PROPAGATION THROUGH A WAVEGUIDE FILLED WITH THE PLASMA OF A POSITIVE DISCHARGE COLUMN. I.

*pp. 55-62.*

Results are presented of an experimental investigation of centimeter wave propagation through a waveguide filled with the plasma of a positive discharge column. The experimental results are compared with the results of theoretical considerations.

*LENINGRAD POLYTECHNIC INST. (6F, 17R)*

— *m w j* —

**V. E. Golant, A. P. Zhilinskii, M. V. Krivosheev, G. P. Nekrutkina:**

### CENTIMETER WAVE PROPAGATION THROUGH A WAVEGUIDE FILLED WITH A PLASMA OF A POSITIVE DISCHARGE COLUMN. II.

*pp. 63-70.*

Nonlinear effects accompanying the waveguide propagation of centimeter waves through the plasma of a positive discharge column are considered herein. Results are presented of an investigation of the wave propagation constant as a function of the high-frequency field innsity for the region in which non-near effects appear. The experimental nd theoretical results are compared.

*PI* *(9F, 8R)*

— *mwj* —

**I. Kurilko:**

### ON THE KINETIC THEORY OF ELECTROMAGNETIC WAVE REFLECTION FROM A MOVING PLASMA.

*pp. 71-77.*

For the practical use of the Doppler ffect particularly in the case of multile reflection, it is necessary that the reection coefficient of an electromagnetic ave from a moving plasma in the refernce system in which the plasma is at est be close to unity. This quantity has een found in a hydrodynamic approxiation for a zero plasma temperature. his problem is analyzed below in a inetic approximation.

*PHYS.-TECH. INST. AN UKRSSR, KHAR'KOV* *(12R)*

— *mwj* —

**. A. Deriugin, M. A. Siga:**

### DISPERSION OF THE MAGNETIC AND DIELECTRIC PERMEABILITY OF ARTIFICIAL DIELECTRICS IN THE 500-35,000 MC RANGE.

*pp. 100-108.*

Results are presented herein of meaurements of the dielectric and magnetic ermeabilities of artificial dielectrics containing copper powders with differnt particle sizes at six frequencies in he 500-35,000 Mc band. The results of he measurements are compared with heoretical curves.

*KIEV UNIV.* *(9F, 11R)*

— *mwj* —

*IVUZ, RT, (3) (6) (1960)*

**O. I. Gubernatorov, V. B. Stepanov:**

### EXPERIMENTAL INVESTIGATION OF THE FREQUENCY LOCKING PROCESS IN A REFLEX KLYSTRON.

*pp. 605 - 612*

Results are presented of an experimental investigation of the synchronization region of a reflex klystron under the effect of an external emf with a frequency close to the natural oscillation frequency.

The locking bandwidth is determined as is the optimum operating region of the locked generator as a function of the voltage on its electrodes and data are presented on the build-up time of the phases of the oscillations to be synchronized.

*KHAR'KOV POLYTECHNIC INST.* *(8F, 7R)*

— *mwj* —

**A. G. Tragov:**

### APPLICATION OF CIRCUIT THEORY TO DIAPHRAGMED WAVEGUIDES.

*pp. 644-51*

Circuit theory is applied to a cylindrical waveguide loaded by irises of finite thickness. The fields in the waveguide are written in the form of a sum of normal modes. A dispersion equation is derived for the diaphragmed waveguide. An equivalent circuit of the cell is represented as a four-terminal network.

*MOSCOW ENG.-PHYSICS INST.* *(3F, 8R)*

— *mwj* —

**K. P. Ivanov:**

### DEMAGNETIZATION OF A FERRITE MEDIUM IN A MICROWAVE FIELD AT A HIGH SIGNAL LEVEL.

*pp. 652-654*

The Bloch equation is used to investigate an infinite ferrite medium subjected to the effect of a microwave magnetic field along the Oy axis and a permanent field along the Oz axis which magnetizes the medium to saturation.

Editor's Comment: In connection with the approximate nature of the Bloch formula, the demagnetizing effect noted by the author requires additional study.

*MOSCOW POWER INST.* *(4R)*

— *mwj* —

**G. V. Grisha:**

### ERRORS IN MEASURING THE PHASE WHEN USING A DOUBLE WAVEGUIDE TEE.

*pp. 663-664*

A double waveguide tee is often used as a bridge in microwave circuits for phase measurement. It is therefore interesting to clarify the dependence of the errors in measuring the phase on the matching of the double tee and the detector head as well as the location of its connection (E or H arm).

*KHAR'KOV POLYTECHNIC INST.* *(2F, 2R)*

— *mwj* —

**V. Iu. Bychkov:**

### USE OF FERRITE GATES IN A CENTIMETER BAND PHASEMETER.

*pp. 665-667*

A phasemeter is described herein in which the influence of the accuracy of the readings being dependent on the relation between the investigated and reference signal powers, and on changes in signal frequency are weakened considerably by using ferrite gates.

*NIRFI, GOR'KII UNIV.* *(3F, 4R)*

— *mwj* —

*RT, 16(2) (1961)*

**A. M. Gasanov:**

### TUNABLE LOW FREQUENCY FILTER OF THE MICROWAVE BAND.

Avtoreferat

*pp. 79-80*

The filter is a strip transmission line of the "conductor between two equipotential plates" type with variable wave impedance.

In contrast to conventional microwave filters, the diameter of the inner conductor is taken identical along the whole length of the filter. The different wave impedances of the individual sections of the filter are achieved by using different spacings between the inner conductor and the side plates. Hence, the side plates of the filter become staggered (the designation "side plates" is only used conditionally).

*(3F, 3R)*

— *mwj* —

*ZTF, 31(2) (1961)*

**K. N. Stepanov, A. B. Kitsenko:**

### ON THE EXCITATION OF ELECTROMAGNETIC WAVES IN A MAGNEOXACTIVE PLASMA BY A BEAM OF CHARGED PARTICLES.

*pp. 167-175*

Cherenkov and cyclotron excitation of "slow" electromagnetic waves in a plasma by a beam of charged particles passing through a plasma parallel to the external magnetic field are analyzed.

*KHAR'KOV POLYTECHNIC INST. AN UKRSSR* *(12R)*

— *mwj* —

*RiE, 6(2) (1961)*

**B. Z. Katzenelenbaum, Z. Z. Malina:**

### COMPUTATION OF JUNCTIONS FOR THE SYMMETRIC MAGNETIC WAVE IN A CIRCULAR WAVEGUIDE.

*pp. 228-233*

Methods are explained of a numerical computation of a symmetric waveguide junction between two waveguides of different diameters for the symmetric magnetic wave.

*IRE AN USSR* *(4F, 8R)*

— *mwj* —

**A. L. Fel'dshtein:**

### SYNTHESIS OF STEP DIRECTIONAL COUPLERS.

*pp. 234-240*

A theory is explained of directional couplers in the form of a chain of segments of coupled lines. The system has theoretically perfect directivity and matching in an unlimited frequency band and optimum (Chebyshev or maximally-smooth) frequency characteristic of power division between the arms. Certain properties of a limiting system with an infinite number of steps are analyzed. Certain tedious computational relations are tabulated.

*(6F, 1T, 9R)*

— *mwj* —

E. K. Zavoiskii, V. A. Dkoriupin:
MAGNETIC ANALYZERS OF RADIATION SPECTRA.

N. P. Grazhdankina, L. G. Gaidukov, K. P. Rodionov, M. I. Oleinik, B. A. Shchipanow:
INFLUENCE OF PRESSURE ON THE ELECTRICAL RESISTIVITY AND GALVANOMAGNETIC EFFECT IN CHROME TELLURIDE.

T. M. Perekalina, A. A. Askochinskii, D. G. Sannikov:
RESONANCE OF DOMAIN BOUNDARIES IN A COBALT FERRITE.

M. I. Podgoretskii, A. V. Stepanov:
ON THE QUESTION OF THE DOPPLER LINEWIDTH OF EMISSION AND ABSORPTION.

V. I. Gerasimenko:
ON SPIN-ACOUSTIC RESONANCE IN PARAMAGNETIC METALS.

V. I. Serdobol'skii:
DISPERSION FORMULAS TAKING INTO ACCOUNT OPTIC INTERACTION.

B. I. Verkin, I. M. Dmitrenko, I. V. Svechkarev:
MAGNETIC PROPERTIES OF BERYLLIUM AT TEMPERATURES FROM 300-4.2°K.

K. P. Belov:
ON CAUSES OF ANOMALOUS LINE BROADENING OF FERROMAGNETIC RESONANCE ABSORPTION IN FERRITES NEAR THE CURIE POINT.

Pribory Tekh. i Eksp., No. 1, 1961

Ia. I. Likhter, S. M. Prozumenshchikov, Ia. P. Sobolev:
SPECTRUM ANALYZER OF SIGNALS OF ALTERNATING FREQUENCY.

F. P. Nifant'Eva:
FERRITE PHASE-SHIFTER OF THE UHF BAND.

L. S. Gorn, B. I. Khazanov:
REVERSING CONVERTER CIRCUIT WITH FERRITE-TRANSISTOR CELLS.

V. N. Kachinskii:
PHASE SHIFTER WITH SMOOTH CHANGE OF PHASE WITHIN BROAD LIMITS.

V. G. Stupak, K. A. Leontovich, I. I. Zaliubovskii:
HIGH-SPEED TIME CONVERTER.

L. M. Prokunin, B. K. Shembel':
ELECTRIC FIELD DISTRIBUTION ALONG THE AXIS OF A TOROIDAL CAVITY.

A. V. Men', I. N. Zhuk:
AUTOMATIC MEASURING LINE FOR SHORTWAVES.

D. I. Mirovitskii, I. F. Budagian, G. G. Valeev:
MICROWAVE REFRACTOMETER WITH SURFACE WAVE LINES.

N. G. Basov, V. S. Zuev:
MOLECULAR GENERATOR WITH
BEAM OF $ND_3$ MOLECULES.

V. F. Bystrov, L. L. Dekabrun, Iu. N
Kil'Ianov, A.u. Stepaniants, E. Z. Utians
kaia:
HIGH-RESOLUTION APPARATUS FOR NUCLEAR MAGNETIC RESONANCE SPECTRA.

V. V. Lemanov:
RADIO SPECTROSCOPE TO STUDY
NUCLEAR MAGNETIC RESONANC
IN SOLIDS.

S. Ia. Iavor, M. Silad'I:
PRODUCTION OF A UNIFORM MAGNETIC FIELD BY A RECTANGULAR SOLENOID OF FINITE LENGTH

V. A. Koptsik, B. A. Strukov, L. A.
Ermakova:
PRECISION LABORATORY CRYOSTAT FOR INVESTIGATION OF ELECTRICAL AND ELASTIC PROPERTIES OF CRYSTALS.

E. N. Lotkova, A. B. Fradkov:
METAL CRYOSTAT FOR OPTICAL INVESTIGATIONS OF SOLIDS AT LOW TEMPERATURES.

V. Iu. Orlov:
LINEARIZATION OF A THERMOMETER SCALE WITH SEMICONDUCTING THERMISTORS.

## Booths

*(Continued from page 129)*

### ALDEN COMPANY
### BOOTH 4314

A new continuous, real-time spectrum analyzer, capable of instantaneous, simultaneous, multi-channel graphic recording of all relative amplitudes and frequencies in any specific bandwidth, is being introduced at the WESCON Show by Alden Electronic & Impulse Recording Equipment Company, Inc., Westboro, Mass.

The analyzer provides automatic, time-based distribution plotting of any parameter which can be analyzed in terms of frequency range and distribution.

The number of channels (60-400); frequencies (in bandwidths of three - 450 cycles); and paper advance rates (from one ft./hr. to one ft./second) can be varied to suit individual requirements.

Another feature of the unit is its "Dual fidelity" response to signals of changing amplitude. As signal intensity increases, markings on electrosensitive Alfax paper, via special, automatically controlled, resilient styli, become not only darker, but wider. This results in more meaningful, more sensitive recording.

**Circle Reader Service Card 147**

—*mwj*—

### SIERRA ELECTRONIC CORP.
### BOOTHS 2006-08

A dual-range frequency selective voltmeter, a versatile, three-way microwave termination and solid-state, compact frequency selective voltmeter are among the new electronic instruments to be introduced by Sierra Electronic Corp., Menlo Park, Cal., at the 1961 WESCON show.

Sierra, a division of Philco Corporation, designs and manufactures a wide range of electronic test instruments and systems. Among the instruments to be shown for the first time at WESCON are:

Model 127A Solid-State Frequency Selective Voltmeter, a completely portable instrument, powered by a rechargeable battery pack; Model 126A Two-Band Frequency Selective Voltmeter, a new instrument designed for measuring frequencies in carrier systems having as many as several hundred voice channels, as well as for general laboratory wave analysis; Model 160-1200 Coaxial Load, a versatile, high-power microwave termination featuring three configurations for different power capacities; Model 186B Coaxial Water Load, a 50 ohm termination, dc to 4000 Mc, 1000 watt average, 10,000 watt peak, SWR less than 1.2.

**Circle Reader Service Card 148**

—*mwj*—

### EDGERTON, GERMESHAUSEN & GRIER, INC.
### BOOTHS 3518-20

Edgerton, Germeshausen & Grier, Inc., Boston, Mass., will show the following items at their booths during the coming WESCON Exhibit:

Ceramic-Metal Hydrogen Thyratrons — long-lasting, miniature tubes for compact modulator design in missile, airborne and ground-based applications; Ceramic Metal Hydrogen Diodes — high-power, high-voltage diodes for use as grid-controlled rectifiers, hold-off diodes, inverse clippers and back-swing clippers — Compact, light and rugged; Ceramic-Metal, Glass-Metal, Triggered Spark Caps — compact, low-cost spark gaps designed for electronic crowbar and high energy switching operations, low trigger energy requirement, fast follow-through after trigger pulse, unaffected by atmospheric conditions, zero filament power requirement; and Milli-Mike Oscilloscopes, Pulse Generators and Accessories — Model 707 Oscilloscope — dc to 2000 Mc bandwidth - 0.2 millimicrosecond rise time-single transient and repetitive signal capability. Sensibility-55 mv/trace width. Small spot size, maximum resolution.

**Circle Reader Service Card 149**

—*mwj*—

### BIRD ELECTRONIC CORP.
### BOOTHS 1922-1924

The Bird Termaline RF Wattmeter and oad will be displayed at WESCON by

he Bird Electronic Corp., Cleveland, hio. Model 6254 is designed to measure ower output and to terminate low pow- 50 ohm systems. Power is direct readng over the range of 30 - 500 Mc with ss than 1.15 VSWR.

Any one of six standard ranges may e specified. Full scale readings are: 25, 0, 100, 250, 500, or 1000 milliwatts.

Also on display will be high power F loads and wattmeters featuring the ird "QC" Series Quick-Change conectors.

**Circle Reader Service Card 150**

—*mwj*—

### GENERAL RF FITTINGS, INC.
### BOOTH 314

General RF Fittings, Inc., Boston, Mass., ill display a new series of weatherproof, hree-pin, bayonet coupling, quick connect/isconnect "TPS" miniature coaxial conectors at WESCON.

Developed under rigid fabricating and esting procedures and approved for use y the U. S. Signal Corps, the connectors re designed to produce minimum electrial discontinuities in a solid dielectric coxial cable of characteristic impedance 50 hms up to a frequency of 10,000 Mc and ated at 500 volts rms at sea level.

Featuring three-pin bayonet coupling ating for maximum reliability, they are vailable in various configurations of lugs, jacks, receptacles and adapters. ompletely weatherproof, other features nclude low VSWR, reduced noise level nd minimum insertion losses. Operating emperature is from —65°F - +260°F. iniature sizes allow use in wider appliations where weight, size and precise oprating performance are a must.

**Circle Reader Service Card 151**

—*mwj*—

### F. C. KENT CORP.
### BOOTH 3705

Waveguide elements—such as elbows, twists, transitions and offsets—in sizes from .09 kMc-48 kMc will be displayed at WESCON by F. C. Kent Corp., Newark, N. J.

Included in the display will be complete formed "runs" to 20 feet in length which can be furnished pretested to very low VSWR.

**Circle Reader Service Card 153**

—*mwj*—

### TECHNICAL APPLIANCE CORP.
### BOOTH 850

Technical Appliance Corp., Sherburne, N. Y., will show expanded lines of new products at the 1961 WESCON Convention. Highlighting the display will be a new microwave antenna/feeds/accessories line developed to meet the increasing demands of industrial and military users of these frequencies.

Also new from the firm will be an exhibit of their rigid transmission line, including a new concept in expansion bullets for use in installations subject to long-run thermal expansion and contraction.

**Circle Reader Service Card 154**

—*mwj*—

### PAPERS

We wish to emphasize again that "the journal" is interested in receiving papers from the industry.

Papers can be addressed to:
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—*mwj*—

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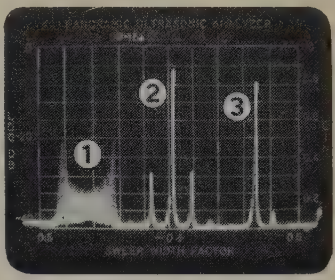

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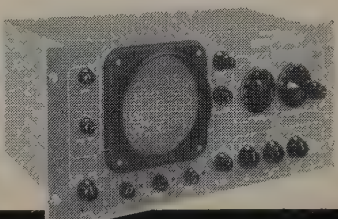

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# FINANCIAL NEWS

## DORNE & MARGOLIN SALES INCREASE 24 PER CENT

Total sales of Dorne & Margolin Inc., Westbury, N. Y., a leader in the development and manufacture of airborne antennas and microwave components, increased nearly 24 per cent between March 31, 1960 and March 31, 1961, Arthur Dorne, president, has announced.

A complete financial report of the company for the fiscal year ended March 31 appears in D&M's "1961 Annual Report". According to the Report, total sales of the company amounted to $2,086,111 as compared with $1,678,664 in 1960. Of the 1961 total, $574,985 of sales resulted from cost-plus-fixed-fee contracts, and $1,511,126 from fixed price contracts. Net income for the year amounted to $41,459.

Among major project accomplishments for the year, the report cites completion of the first equipment for a space vehicle—the telemetry antenna system for the Caleb air-launched two-stage rocket; beginning of pilot production for a quantity of AN/ALA-12 systems, and production of new antennas for VOR omni range stations, under contract to the Federal Aviation Agency; design of an antenna for a high speed (Mach 2) sled; and the design of a low cost, high performance commercial antenna to be used with DME navigation receivers on private aircraft.

*—mwj—*

## LFE REPORTS $50,929,000 GROSS INCOME

A gross income of $50,929,000 for the fiscal year ended April 30, 1961, has been reported by Laboratory For Electronics, Inc., Boston, Mass.

In the company's annual report to stockholders, Henry W. Harding, president, said this figure represents a six per cent increase over the previous year's consolidated sales figure of $48,114,000. Combined net income was $1,891,000—up 15 per cent from fiscal 1960's net of $1,648,000.

On the 1,136,636 shares of common stock now outstanding, this amounts to combined earning's per share of $1.66. On a pre-merger basis, LFE earnings per share would have been $2.58 compared with fiscal 1960's $2.23 per share.

Research and development programs have been receiving new emphasis, stockholders learned in the report. Expenditures on company-sponsored projects during fiscal 1961 were $1,120,000 a 93 per cent increase over the previou year with another large increase planne for this year.

*—mwj—*

## LITTON DECLARES 2½ PER CENT COMMON STOCK DIVIDEND

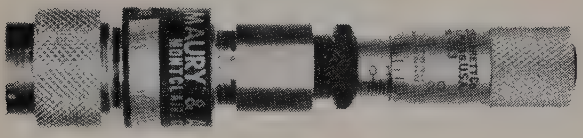
Litton Industries, Beverly Hills, Cal has declared a 2 1/2 per cent commo stock dividend to be paid on Oct. 20, 196 to stockholders of record Oct. 6, 196 Charles B. Thornton, president and chai man of the board, has announced. Th announcement was made following meeting of the Board of Directors.

The last previous dividend paid b the firm was in October 1960 and wa also a 2 1/2 per cent common stoc dividend.

At the close of the first nine month of the present fiscal year on April 30 Litton had total sales of $165,698,000 an increase of 23 per cent over the $134, 459,000 for the same period a year ago Net earnings for the period, after foreig and federal taxes of $6,422,000, wer $6,821,000, an increase of 25 per cen over the net for the same period las year.

*—mwj—*

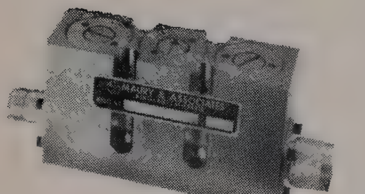
TUNEABLE LOADS
(PATENTS PENDING)



1.02 MAX VSWR

THE MOST PRECISE MICROWAVE TERMINATION AVAILABLE. TWO MODELS COVERING 250 TO 4000 MC.

BAND PASS FILTERS



TUNEABLE CAVITY TYPE BAND PASS FILTERS, FOR MISSILEBORNE OR LABORATORY APPLICATIONS. STANDARD MODELS AVAILABLE FROM 100 TO 4000 MC WITH CHOICE OF REJECTION CHARACTERISTICS, AND FEATURING LOW INSERTION LOSS AND VSWR.

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# NEW LITERATURE

## ALFORD ISSUES 1961 CATALOG

The 1961 Alford Manufacturing Co., Boston, Mass., Catalog describes their rf instruments and coaxial components; gives characteristics, dimensions, and prices of slotted lines, tapered reducers, adapters, instrument loads, calibrated mismatches, impedance-matching tuners and networks, impedance-standard lines, automatic impedance plotters, transmission-line hybrids, rf bridges, coaxial switches, line stretchers, variable calibrated attenuators, matching tees, and detector-mixer.

It also includes ordering information and list of sales offices; 30 pages; free on letterhead request to Alford Manufacturing Company, 299 Atlantic Avenue, Boston 10, Massachusetts.

— *m w j* —

## MICROWAVE INSTRUMENTATION CATALOG OFFERED BY WAVE PARTICLE

A new short form catalog by Wave Particle, Richmond, Cal., pictures and describes the firm's microwave signal sources, levelers, amplifiers, low-noise amplifiers, and power supplies.

Included are two new products: A permanent magnet focused TWT amplifier with solid state power supplies, and an ultra low-noise amplifier.

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## PHILCO'S COMMUNICATIONS SYSTEMS DIVISION DESCRIBED

A brochure is now available describing the functions and responsibilities of Philco Corporation's Communication Systems Division, Ft. Washington, Pa.

The division which is one of five of Philco's Government and Industrial Group is a management organization whose primary responsibility is the technical management of large and complex communications systems for both government and industry. This work covers all phases of electronics, including engineering, procurement and installation.

Among the major tasks accomplished by the Communications Systems Division are, Defense Communications Control System, the Caribbean Keying Link in Puerto Rico for the U. S. Army, the U. S. Air Force Criticomm Improvement Program, the Quick Fix phase of the modernization of the U. S. Air Force's Aircom communications system, microwave intra-station communication link-ages for the Strategic Air Command at several of its bases under Project Short Order, and Siskiyou Telephone Company microwave system which is one of the longest independent toll line systems in the United States and is located in Northern California.

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## PGMTT DIGEST STILL AVAILABLE

Copies of the 1961 PGMTT Nationa Symposium Digest ("Digest of Technica Papers") are still available at $3.00 per copy. The Digests may be obtained from Frank Reggia, Microwave Branch 250 DOFL, Washington 25, D.C. Remittance should be made payable to 1961 IRE-PGMTT National Symposium.

The Digest covers twenty contributed papers which constituted four sessions describing millimeter waves, parametric devices, ferrites, and plasmas. Six invited papers for the two panel sessions on high power microwave techniques and low noise microwave amplifiers are summarized. "Elementary Consideration of Noise Performance," a complete paper included in the Digest formed the basis of discussion for the System and Receiver Noise Performance Clinic.

— *m w j* —

## PRD'S 1961 SHORT FORM CATALOG AVAILABLE

Bulletin 800, PRD's 1961 four page, 2 color, short form catalog is available free from PRD Electronics, Inc., Brooklyn, N. Y., manufacturer of microwave and electronic test equipment. It categorizes hundreds of products by frequency ranges, waveguide sizes, prices, etc.

Featured, also, in this line of microwave and electronic test equipment, are PRD's newest models of Attenuators, Slotted Sections, Isolators, Mounts, Frequency Meters, Adapters, Klystron Power Supplies, Calorimetric Power Meters, Signal Sources, and numerous other items of Waveguide and Coaxial Test Equipment.

A complete listing of PRD's Domestic Sales Representatives and regional Applications Engineering facilities as well as photographs of new instruments are also shown.

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## RODELIN 2-WAY ANTENNAS AND ACCESSORIES DESCRIBED IN CATALOG

An expanded 24 page, fully illustrated, ew issue of catalog 598, describing comlete line of 2-Way Antennas and accesories has been announced by Prodelin c., Kearney, N. J.

The catalog incorporates electrical and echanical specifications, impedance urves and vertical radiation patterns. he engineering data section contains disussion on antenna gain and propagation, ccompanied with examples and curves,

It also contains full information on ew foam polyethylene insulated, alumium sheathed, Spir-O-foam coaxial transission line. Spir-O-foam, with its atched companion Spir-O-lok connector. ssures low-loss broadband performance eaturing simple installation procedures nd reliable service.

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—*mwj*—

## TACO CATALOGS MICROWAVE ANTENNAS

Complete technical data on a wide ange of spun and mesh Microwave Anennas is available for the first time in a ew catalog from Taco, Sherburne, N. Y. The booklet itemizes and describes Plane and Dual Polarized Parabolic Anennas in frequency ranges from 806 Mc o 13.2 kMc. Dependent on specific types mployed, these units are used for UHF Translator, Studio-Transmitter Link, Government, Operational fixed, Remote Pickup, Industrial Service and Common Carrier applications. Typical electrical specifications are given for all of the types described.

Special features include a variety of frequency ranges in either mesh or spun construction to meet wind and ice load conditions, five reflector sizes and a variety of feeds — most designed for mounting from either the front or rear of the reflector.

A full range of mounts are also catalogued including standard and heavy duty pipe mounts, roof mounts, tilt mounts, and a variety of non-standard mounts to meet specific requirements. Radomes, thermostat kits, and feed and reflector heaters are also described. Windload specifications, packaging and shipping data is included to enable the user to cover all requirements from one source.

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—*mwj*—

*(Continued on page 138)*

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## New Literature

*(Continued from page 137)*

### AIRBORNE TELEMETRY EQUIPMENT DESCRIBED

Five equipments for Airborne Telemetry Systems are described in a new six page data sheet just off the press, published by Vitro Electronics, Silver Springs, Md., producers of Nems-Clarke equipment.

The data sheet describes an FM Phase-Lock Telemetry receiver, a preamplifier, a multicoupler for up to eight receivers, a diversity combiner for up to four receivers, and a spectrum display unit for monitoring up to four receivers. All units are designed for airborne system applications in which performance and reliability are of greater importance than size and weight.

The equipments mentioned represent the necessary building blocks, which, when used in various multiples and combinations, produce a variety of systems for receiving and improving the signals of telemetered data to be recorded.

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*—mwj—*

### LITTON INTRODUCES MILLIMETER WAVE TUBE CATALOG

The Electron Tube Division, Litton Industries, San Carlos, Cal.,, announces the availability of a millimeter wave tube catalog featuring microwave products marketed by Elliott-Litton, Ltd., of London, England.

The 52 page catalog provides data and outline drawings of monitor diodes, noise tubes, high power floating drift tube klystrons, reflex klystrons, klystron power units, noise diode power units, monitor diode supply and indicator units, noise tube mounts and adjustable waveguide mounts.

**Circle Reader Service Card 161**

*—mwj—*

### DYNAMIC TESTING OF RADAR EXPLAINED IN REMANCO PUBLICATION

A new, four-page brochure titled "Dynamic Radar Simulators," describing the reasons for dynamic testing of radar, what it is and what it can do, is now available from Remanco, Inc., Santa Monica, Cal.

A list of general specifications is also provided as an aid in determining parameter limitations for radar simulators.

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*—mwj—*

*(Continued on page 139)*

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(Continued from page 138)

### CATALOG GIVES DATA ON NEW SERIES

Catalog XT-61 provides data on a new eries of microwave 20, 30, 40 and 50 db rossguide couplers available in EIA VR90, 112, 137, 187 and 284 waveguide izes, from Microwave Development Labratories, Inc., Natick, Mass.

This eight page catalog contains color-llustrated diagrams and performance urves. In addition to the electrical and nechanical data, a glossary of nomenclaure and applications are given. Also inluded is a guide to facilitate the orderng of couplers for specific requirements.

**Circle Reader Service Card 163**

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### CATALOG LISTS LEL LINE

LEL Inc., Copiague, N. Y., announces hat its line of microwave receiver mixer-preamplifiers, IF and RF amplifiers, parametric amplifiers, and laboratory receivers is described in a new 48 page 1961 catalog.

General notes on the application of the mixer-amplifier units in radar receiver design are included in the catalog. Over 700 combination mixer-amplifier units are listed, thus providing a standard catalog type for a wide range of diverse system requirements.

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### REPRINT OF TECHNICAL ARTICLE AVAILABLE

The Weinschel Engineering Company, Kensington, Md., has available a limited number of reprints of an article entitled, "A Subtle Error in RF Power Measurements" written by S. J. Raff and G. U. Sorger.

The article, which originally appeared in the IRE Transactions on Instrumentation, deals with a particular type of error which arises in RF power measuring bridges which supply simultaneous ac and dc power to the bolometer for biasing, compensation or balance detection. In such bridges, the instantaneous power delivered to the bolometer will vary during the audio cycle, causing a small variation in the temperature and hence in the resistance of the bolometer.

These variations, even though extremely small, can cause systematic errors in the power measurement which are very significant when accuracies in the order of 1 per cent are desired. The article is complete with block and schematic diagrams as well as graphs to illustrate the text.

The article may be obtained by writing Weinschel Engineering Company, 10503 Metropolitan Avenue, Kensington, Maryland. All requests must be made on company or organization letterhead.

*—mwj—*

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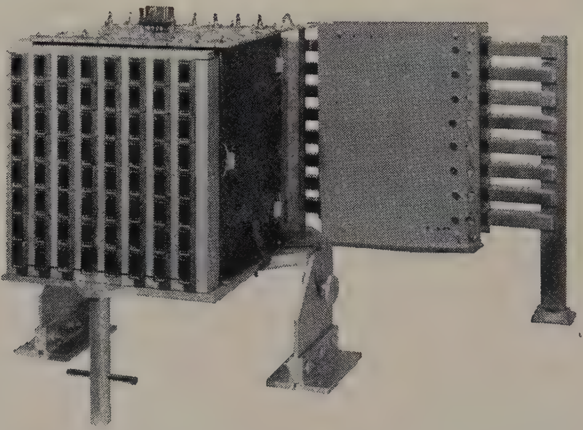

■ Requirements of new and continuing projects concerned with space vehicle communications, navigation, and radar have created new openings for electromagnetic theory specialists as well as antenna engineers. The scientists and engineers of the Research and Development Division of the Hughes Aircraft Company Aerospace Group in Culver City are providing broad scientific and technical leadership to government and company funded programs on advanced airborne and space electronic systems, air to air missiles, ballistic missiles, and satellite and interplanetary communication systems. As part of this team, the Antenna Department is responsible for a diversified program of antenna research and development in the following specific areas:

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3. Statistical analysis of scattering propagation.
4. Pattern synthesis from sources on arbitrarily curved surfaces.
5. Aperture control by application of solid state devices.
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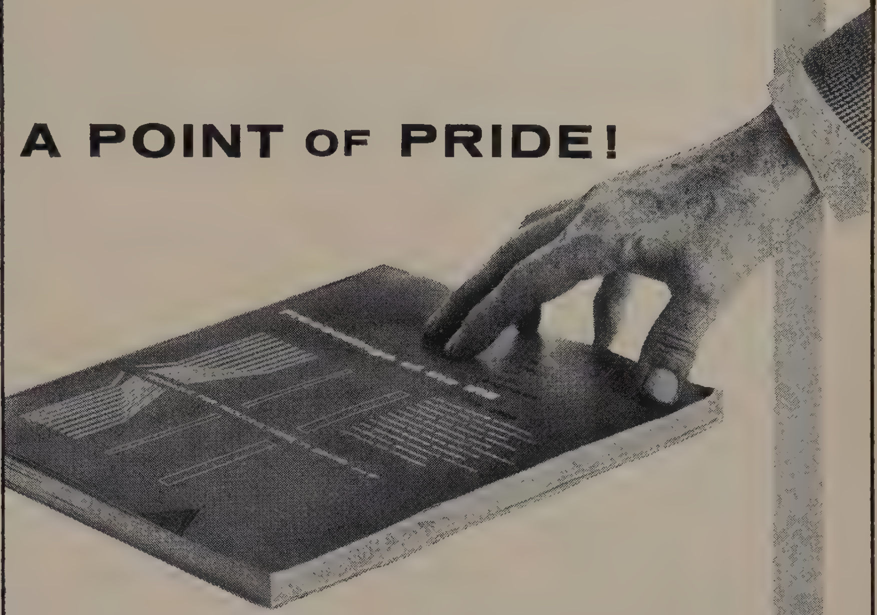

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- controlled junction capacity spreads

**simplified overall amplifier design**

**ELECTRICAL CHARACTERISTICS (measured at 25°C ambient temperature)**

| SYM. | PARAMETER | TEST CONDITIONS | AP-1 | AP-2 | AP-3 | AP-4 | AP-5 | AP-6 | AP-7 | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| $BV_R$ | Reverse Breakdown | $I_R = 10\ \mu a$ | 6 min. for AP-1 thru AP-5 | | | | | 5 min. | 4.5 min. | V |
| $C_T$ | Total Capacitance | V=O, f=lmc | .5 to 1.5 for entire series | | | | | | | $\mu\mu f$ |
| Q | Figure of Merit | $V_R = 2v$, f=10kmc | 6 min. | 7 min. | 9 min. | 11 min. | 13 min. | 15 min. | 19 min. | |
| fco | cut off freq. | $V_R = 2v$ | 60 min. | 70 min. | 90 min. | 110 min. | 130 min. | 150 min. | 190 min. | kmc |

Tyco Semiconductor gallium arsenide varactor diodes have successfully completed 2000 hours of operating life testing — and are regularly subjected to humidity, salt spray and drop testing operations prior to shipment.

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# SHAKEDOWN SURVIVAL

By LLOYD A. ADDLEMAN

There is a great deal of discussion on the subject of an electronics industry shakedown. Since the phenomena is based on the competitive superiority of the large company, these discussions exhume many large company vs. small company arguments. I don't want to drag the arguments around unnecessarily but it might be interesting to consider those that are applicable to the present situation.

The shakedown atmosphere has encouraged the acquisition operations of larger firms and has furnished them with some apparent substance for their "Sell". These arguments take two directions:

- — That fierce competition for the mass produced items will reduce the number of manufacturers to some much smaller number and that the victor will be the large company with the financial resources necessary to provide facilities for the mass production. A parallel is often drawn between electronics and the automobile industry.
- — That the large military market has long been shifting towards the systems management concept with a large corporation as the system manager and that these corporations are self-sufficient and will tend to operate in this manner in spite of small business laws.

These two arguments lead many to conclude that the only solution for the small firm is to join a larger one or seek sufficient capital to rapidly become large itself.

Although both of these arguments are, in part, true. there are valid counter arguments which seldom are used or, at least, seldom appear in print. These lead me to think that there will be plenty of room for a properly operated company to grow and avoid being a victim of the shakedown.

First, the electronics market is much more diverse than the automobile industry. The electronics industry might better be compared to the "mechanics" industry since it can perform a great variety of functions. Even the automobile industry in its largest sense supports a great number of small firms. Specialized vehicles, such as trucks and a large number of the parts, both replacement and prime, are supplied to the larger firm by small business.

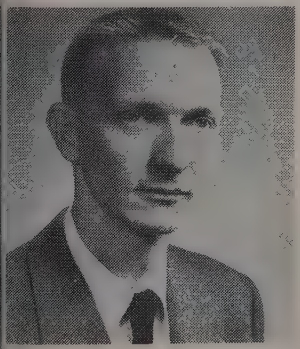
There are other examples of great diversification of suppliers — home appliances are an example when considered in their great variety, such as the whole gamut from washers to table lamps.

There is an advantage which the small businessman may realize due to the rapid changes in modern technology. The larger companies, having considerable investment in mass production tooling, find themselves less able to cope with these changes. For example, the larger aircraft companies are struggling to get into new space age activities as well as electronics and neither the staffs or the tooling quite fit. On the other hand, the next era may involve an "airplane in every garage" and the aircraft companies may all be engaged in electronics. These same aircraft companies are not equipped for competition in this field any more than they are for competition in the electronics field.

Another phenomena is plaguing the mass production man. Foreign manufacturers have completely taken over the manufacture of radios and the automobile industry has had large losses of market to them.

It would seem that we are entering an era, at least in the United States, in which technical capability will be more important to business success than the capital requirement which was needed in the past to support mass produced items of less technical complexity.

The argument for using large firms for military systems management seems to be based on a need for the



**LLOYD A. ADDLEMAN** was born in Columbus, Ohio on April 1, 1927. He received his BEE degree from Ohio State University in 1949.

During 1949 and 1950, he was employed at Hazeltine on the development of radar and IFF equipments. From 1950 to 1952, he was a project engineer for the Press Wireless Manufacturing Company on secure communications systems. He was with Sylvania Electric Products Physics Laboratories and Electronic Defense Laboratories from 1952 to 1956.

In April, 1956, he and three others formed Melabs where he is now president. He is a member of Tau Beta Pi and Eta Kappa Nu.

financial resources of the giants to operate the programs. This is, in turn, based upon some current government contract forms and habits of operation. The government seems to be in the odd, though not unusual, position of buying what it does not need — financial capability. What it does require is competent business and technical personnel who are not influenced by upper echelon company management in their choice of subcontractors or by the battle to "lock up" large scale follow-on production orders to support other company facilities.

There is little reason to believe that the most qualified people in either technical or business fields seek employment with the larger corporations so that better system management teams might be found within the small company frameworks. Our experience has been that the larger corporations frequently operate their systems work on government funds, committing very little, if any, of their own dollars. Present government billing procedures will allow a small company to operate large systems programs as long as a fair part of the work is subcontracted; it is often appropriate to subcontract large portions of the system to obtain the best technical teams and/or equipment.

In the past, large contracts usually meant large quantities. Today, the era of mass production in military systems is waning as the weapons are becoming more effective and fewer in number, though more complex and embracing a large number of highly technical parts. Many of the large electronics companies have been caught with large capital investments in mass production operations, whereas the emphasis is now on research and development, and production runs which would more accurately be termed model runs. This work is better suited to small companies.

If the technical aspects of competition are to become more important than capital, those companies which are in the best environment for technical accomplishment will be most likely to survive. These environmental factors are:

- — Large corporations have found that they should isolate their technical staff and try to provide the autonomy and incentive atmosphere found in a smaller operation. These attempts are seldom, if ever, very successful. If they make these moves they must also believe in the advantages.
- — Since it is very difficult for a large company to multiply its size by any large number, let alone for an individual to cause this growth by his own efforts, it is likewise difficult to provide such incentive by ownership participation (stock options etc.).
- — The more competent technical leaders tend to be individualists and often take a dim view of the corporation man as they conceive of him; feeling that he must too often sacrifice freedom and even ethics to satisfy the desires of all too distant management.
- — As a company grows larger, management loses contact with the individual and seeks to measure performance by some more ready measure, such as who works the most hours or who has the ability to surround himself with the largest staff.

To sum it up, I believe that the shakedown, although real, will not seriously affect well managed small business. These firms will survive because they can attract and hold many of the best people and success will depend more on the individual and less on capital than ever before.

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nplete this section ONLY if you are PRINCIPALLY engaged in COMPONENTS 0-29

0-65 ☐ ANTENNAS
- 1-65 ☐ Large
- 5-65 ☐ Communication
- 7-65 ☐ Tracking
- 1-66 ☐ Airborne
- 3-65 ☐ Small (under 10')
- 9-65 ☐ Detection
- 0-66 ☐ Tropo Scatter
- 3-66 ☐ Other ________ Type

0-67 ☐ TEST EQUIPMENT

________ Type

7-67 ☐ TUBES
- 9-67 ☐ Planar
- 0-68 ☐ Passive devices
- 7-68 ☐ Storage
- 1-68 ☐ Klystron
  - 3-68 ☐ High power
  - 5-68 ☐ Low power
- 9-68 ☐ Gaseous discharge
- 9-69 ☐ Duplexers
- 7-69 ☐ Crossfield
- 1-69 ☐ BWO
- 3-69 ☐ TWT
  - 9-83 ☐ High power
  - 9-84 ☐ Low power
- 0-69 Magnetron
  - 9-81 ☐ High or 9-82 ☐ low power
- 5-69 ☐ Other ________ Type

1-70 ☐ SOLID STATE
- 3-70 ☐ Amplifiers
- 5-70 ☐ Transistors
- 7-70 ☐ Paramagnetic
- 9-70 ☐ Thermoelectric
- 7-71 ☐ Masers
- 9-71 ☐ Diodes

- 0-72 ☐ Ferrimagnetics
- 1-72 ☐ Parametrics
- 0-71 ☐ Ferrites ________ Type
- 3-72 ☐ Crystals
- 5-72 ☐ Infrared
- 7-72 ☐ Other ________ Type

3-73 ☐ TRANSMISSION LINES
- 7-73 ☐ Coaxial
- 9-73 ☐ Waveguide

0-74 ☐ SMALL COMPONENTS
- 1-74 ☐ Bolometers
- 3-74 ☐ Holders & Mounts
- 5-74 ☐ Horns
- 7-74 ☐ Hybrid Junctions
- 1-75 ☐ Switches
  - 5-76 ☐ Coaxial
  - 7-76 ☐ Waveguide
- 1-76 ☐ Other ________ Type
- 3-75 ☐ Filters
- 5-75 ☐ Attenuators
- 7-75 ☐ Limiters
- 9-75 ☐ Diplexers
- 0-76 ☐ Terminations

9-76 ☐ WAVEGUIDES
- 0-77 ☐ Rigid
- 1-77 ☐ Flexible
- 5-73 ☐ Transitions
- 3-77 ☐ Windows

0-78 ☐ MILLIMETER ________ Type

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☐ Please check here if you are engaged in Research and Development work and if your activities encompass general phases of "the microwave journal".

3-79 ☐ MAGNETICS ________ Type

9-79 ☐ CRYOGENICS ________ Type

3-86 ☐ PLASTICS
- 5-86 ☐ Radomes
- 7-86 ☐ Insulation
- 9-86 ☐ Packaging
- 3-87 ☐ Other ________ Type
- 0-87 ☐ Dielectrics
- 1-87 ☐ Absorbers

5-87 ☐ MATERIALS
- 7-87 ☐ Garnets
- 9-87 ☐ Germanium
- 3-88 ☐ Galium arsenide
- 5-88 ☐ Inter Metal. Comp.
- 1-88 ☐ Ferrites
- 9-80 ☐ Silicon
- 9-88 ☐ Other ________
- 7-88 ☐ Rubies

0-89 ☐ PLASMA ________ Field

5-89 ☐ SPECTROSCOPY

7-89 ☐ OPTICS

9-89 ☐ NUCLEAR
- 0-90 ☐ Linear Accelerator
- 1-90 ☐ Cyclotron
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- 3-90 ☐ Other ________

9-90 ☐ FERROELECTRICS

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☐ RESEARCH
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☐ APPLICATIONS
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☐ SALES
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☐ OTHER

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0-26 ☐ **RADAR** ______________ Type

1-27 ☐ **MISSILES**
3-28 ☐ Tracking 5-28 ☐ Guidance
9-28 ☐ Other

3-30 ☐ **GROUND SUPPORT** ______________ Type

7-28 ☐ **AIRBORNE** ______________ Type

0-31 ☐ **ASW** ______________ Type

7-31 ☐ **TELEMETERING** ______________ Type

9-32 ☐ **DATA PROCESSING** ______________ Type

5-34 ☐ **RADIO ASTRONOMY** ______________ Type
1-32 ☐ Radiometry 7-34 ☐ Other

1-41 ☐ **COUNTERMEASURES** ______________ Type

3-41 ☐ **POINT TO POINT RELAY LINKS**
5-42 ☐ Commercial MW Relay User
☐ Industry served ______________
9-42 ☐ Relay equipment manufacture

5-41 ☐ **DETECTION SYSTEMS**
7-41 ☐ Infrared
9-41 ☐ Other ______________ Type

1-43 ☐ **SONAR**
3-43 ☐ Ultrasonics
5-43 ☐ Other ______________ Type

1-44 ☐ **COMMUNICATIONS**
3-44 ☐ UHF, VHF
5-44 ☐ Space Communications
7-44 ☐ SSB Trans.
9-44 ☐ Radio, Television
7-45 ☐ Mobile
9-45 ☐ Data Transmission
3-45 ☐ Other ______________ Type

0-63 ☐ **SUBSYSTEMS**
1-63 ☐ Power supplies
1-45 ☐ Transmitters
0-45 ☐ Receivers
9-63 ☐ Circuits
7-63 ☐ Other ______________ Type

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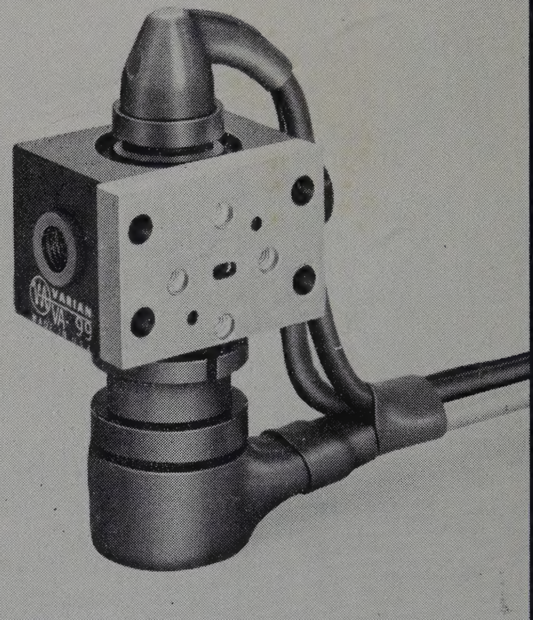

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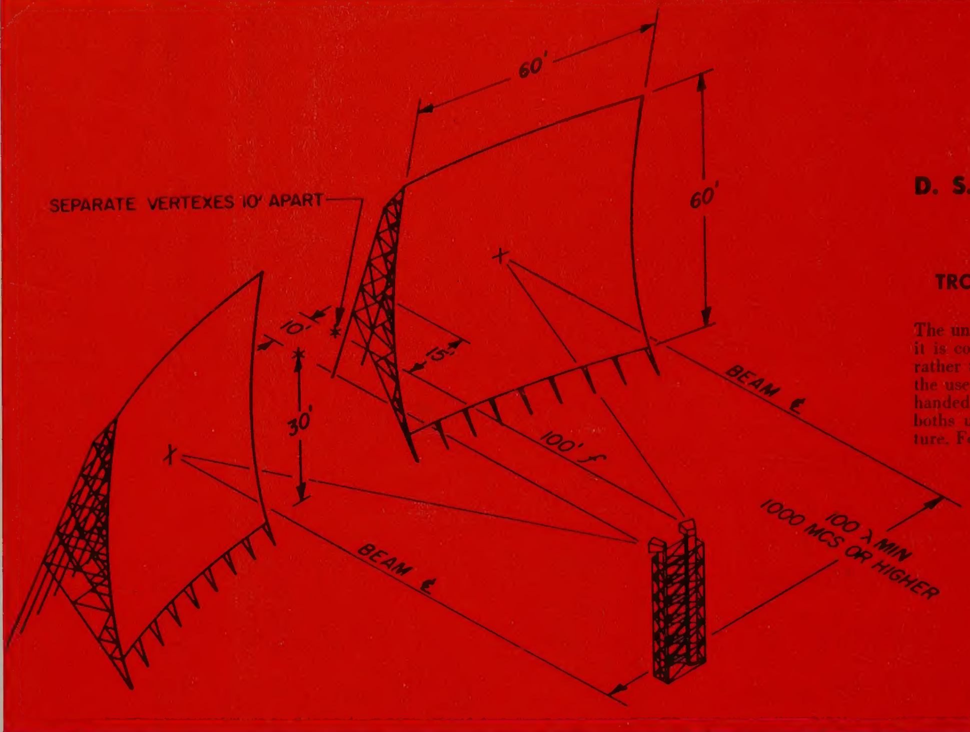

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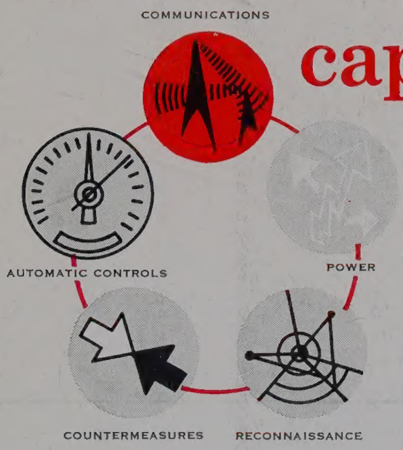

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